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Eclipse Reports

The total solar eclipse of July 9 did not receive much attention on the part of American astronomers until a month or two before it occurred. This was the natural consequence of several factors: (1) the war in Europe; (2) the relative inaccessibility of the path of totality; (3) the comparatively short period of totality; (4) the altitude of the sun at totality; (5) difficulty of travel in general.

However, with the rather sudden arrival of V-E day, the minds of the astronomers as well as of other persons readily turned from thoughts of war to the normal activities of peace. For them the lure of a total eclipse of the sun was at hand. In the few weeks preceding the date of the eclipse, word came from many quarters of eclipse expeditions which were being planned for various places along the path from Idaho to Hudson Bay. The writer fell under the spell almost at the last moment. Being able to secure transportation to Roblin, Manitoba, he accepted the invitation of Dr. Charles H. Smiley to join his party at that place. But clouds proved to be the undoing of the efforts of this party. After standing in the chill of the early morning from first to fourth contact looking in vain for a glimpse of the sun, he has to report that he saw nothing but clouds. Near the time of totality, one observer described the situation somewhat wistfully and picturesquely when he said, "I can't even see where to point this—camera." Some expeditions, however, were more fortunate, as is indicated by the following reports.

The several expeditions to Canada give varied accounts of their experiences as far as eclipse results are concerned. But they are unanimous in expressing their appreciation for the cordial and helpful hospitality they received. Nothing, within the power of the people of the several communities, was left undone for the comfort of the observers and the success of their undertakings. Indicative of the friendly spirit which prevailed in the days just before the eclipse is this sketchy conversation. A prominent Winnipeg citizen facetiously remarked to the writer that eclipses in the United States are, of course, bigger and better than those in Canada. He was assured that this is not the case because both countries have the same sun and the same moon.

C. H. Gingrich.

THE BROWN UNIVERSITY-SKYSCRAPERS EXPEDITION, ROBLIN, MANITOBA

A party of nine persons under the leadership of Professor Charles H. Smiley of Brown University travelled from Providence, Rhode Island, to Roblin, Manitoba, near the Saskatchewan boundary, to observe the total solar eclipse of July 9, 1945. The expedition was sponsored jointly by Ladd Observatory of Brown University and Skyscrapers, Inc., the amateur astronomical society of Rhode Island. It was the fifth solar eclipse expedition in fourteen years to be sent out under this joint sponsorship.

The persons making up the party were Professor and Mrs. C. H. Smiley; Miss Maribelle Cormack, President of the Skyscrapers; Mr. F. W. Hoffman, past president of the organization; Miss Wilhelmina Null and Miss Mary Quirk, science teachers, in Rhode Island schools; Rev. Wm. G. Fagan; Miss Evelyn Lindsay and Miss Priscilla Biron, students at Pembroke College of Brown University. Dr. Curvin H. Gingrich of Carleton College, Editor of POPULAR ASTRONOMY, joined the party at Roblin by special invitation.

Two problems were undertaken by the group: the determination by visual means of the absolute value of the brightness of the outer corona and of the zodiacal light in the vicinity of the sun. Four modern photometers, capable of reaching low levels of brightness, were available, and were to be operated by Mr. and Mrs. Smiley and the Misses Biron and Lindsay. These persons were to be dark-adapted through the use of special Welsh dark glasses and variable density Polaroid glasses. The scales of the photometers were to be read by the Misses Null, Quirk, and Cormack, and Mr. Fagan. It was planned to measure brightness around an annular region approximately 3° from the center of the sun. Neutral density filters were at hand to extend the range of the photometers up or down as was necessary.

Dr. Gingrich carried the important oral count of seconds which enabled the various members of the party to coordinate their activities. Mr. Hoffman had prepared an elaborate set-up in which timed motion pictures of the four contacts were to have been taken at high speed. The 16 mm motion picture camera with telephoto lens was to have operated at 64 frames per second; into it, a neon light was flashed regularly by a chronometer which recorded a signal simultaneously on a tape chronograph. All other members of the party were to have made visual estimates of the times of first and fourth contacts, and six were to have estimated the times of second and third contacts. Time signals from the National Bureau of Standards, station WWV, in Washington were used as a standard.

Through contacts established in advance by the Reverend Mr. W. G. Fagan, the choice of an observing site, arrangements for transportation to and preparation of the site as well as for meals were greatly facilitated by the Reverend Mr. H. B. Ellison of Roblin. The location chosen

was a high point of land about four and a half miles west and one and one-half miles north of Roblin on the farm of Mr. J. A. Gill. Mr. Fred McDuffe took care of the clearing of the low brush from the site and moved a small granary into position for the protection of observers and instruments from the elements. The party took rooms, breakfast, and dinners at the excellent Roblin Hotel which was under the friendly supervision of Mr. and Mrs. A. G. Gleiser. Delicious and sumptuous lunches were served at the farm home of the Gills near the eclipse position; members of the party remember with pleasure their cordial hospitality. Only praise can be said for the whole-hearted cooperation and the friendly reception given the expedition by the townspeople of Roblin.

Miss Mary Quirk took charge of the determination of the precise longitude and latitude of the chosen point. Several hundred observations were made of celestial objects with a reflecting circle and a sextant; all members of the group shared in this work but the major burden was carried by the Misses Quirk, Null, Biron, and Lindsay, and Mr. Smiley.

Although the eastern sky was beautifully clear and the air was quite cold (39° F) at sunrise on July 9, heavy clouds moved in from the west and filled the sky long before first contact was due. No break in the clouds was noted until after the fourth contact was past. Mr. Hoffman went through his complete routine of photography just as if the skies were clear at each of the four contacts, but to no avail. The persons who were to have measured the brightness of the outer corona, turned their photometers instead on the clouds—two on the zenith, one at 45° altitude and one at 30° in the direction of the oncoming shadow. The comparison of these measures with what might have been expected theoretically is not yet complete but promises to be interesting. The smoothness of the observed data leads one to believe that, had the skies been clear, the program of measures on the outer corona would have been successful.

The one cheerful note in an otherwise unhappy day came when it was announced that the Skyscrapers had had the wisdom to insure against clouds. The members sighed and turned their thoughts to the solar eclipse of May 20, 1947, which will be seen in its total phase from the east coast of South America.

CHARLES H. SMILEY.

LADD OBSERVATORY, PROVIDENCE, R. I.

THE PHILADELPHIA BULLETIN—FRANKLIN INSTITUTE—UNIVERSITY OF PENNSYLVANIA EXPEDITION, WOLSELEY, SASKATCHEWAN

The Cook and Flower Observatories of the University of Pennsylvania possess a number of instruments suitable for eclipse observations. Full cooperation from Dr. Charles P. Olivier, Director of the Observatories, and other University officials made it possible for these instruments to be used for an expedition planned at The Franklin Institute

and financed by the Philadelphia *Evening Bulletin*, the afternoon paper of largest circulation in America. The scientific members of the expedition consisted of Dr. Roy K. Marshall, Director of the Fels Planetarium of The Franklin Institute, Dr. Orren C. Mohler, astronomer at the McMath-Hulbert Observatory of the University of Michigan, and Dr. Richard M. Sutton, professor of physics at Haverford College, Pennsylvania. The Philadelphia *Evening Bulletin* sent a reporter, Harry G. Proctor, the Canadian Press and Associated Press sent a representative, Douglas Green, and a radio engineer, Richard Shipp, was on the spot to operate the remote control apparatus for a broadcast during the eclipse by direct wire to stations WPEN in Philadelphia and WWDC in Washington. A volunteer, Master Technical Sergeant George Steinhardt of the U.S.M.C., went along at his own expense to assist in the radio work.

The town of Wolseley, Saskatchewan, was chosen because it had more facilities than many of the other towns on the flat prairie land in the eclipse path. For the instruments, 110 volt alternating current was desirable; without this, it would be necessary to devise gravity drives for the mechanisms. A lumber yard was an asset, for the construction of long camera tubes and piers. These facilities were available in Wolseley. The use of the school property was granted, and the instruments were finally established there, in an excellent location with a good horizon, the largest obstruction being a tree only about four degrees high. The building not only offered shelter for the packing cases and supplies, but provided accommodations for cots for the members of the expedition, for rest during the two nights preceding the eclipse. Two rooms of the building were heated for the convenience of the visitors, on the night before the eclipse, when the temperature fell almost to freezing.

The heavy equipment was shipped from Philadelphia in four large wooden cases, totalling about 1200 pounds, on June 25; it arrived in Wolseley on July 4. The optical parts, the photographic materials, small cameras, and other lighter materials, amounting to about 300 pounds, left Philadelphia in a chartered two-motored Cessna T-50 plane, in the afternoon of July 4. Dr. Marshall accompanied these materials, and Dr. Mohler was picked up in Detroit. The night was spent in LaCrosse, Wisconsin, and on the next day the plane reached Regina. About 2:30 p.m. on July 6, Dr. Mohler, Dr. Marshall, and Douglas Green, who had been picked up in Regina, drove to Wolseley. Within an hour or two, the heavy express had been delivered to the school and construction of the camp was under way, approximately 60 hours before the time of the eclipse.

On Saturday and Sunday, the services of a local carpenter, Wilbur Willis, and his young helper, made it possible to have everything in readiness. A small packing case served as the pier for the equatorial mounting for the twin 4-inch Ross-Fecker cameras of the University of Pennsylvania. A large packing case, resting on a concrete walk and

held stationary by planks and stakes driven in the ground, served as the pier for the single-mirror heliostat of the Cook Observatory, which fed the 5-inch lens of 40 feet focal length, and the two-mirror coelostat of The Franklin Institute, which fed the 6½-inch lens of 18 feet focal length. Wooden tubes of rectangular cross-section served as the bodies of the cameras, and ordinary wooden plate holders, 11x14 inches in size, were used with them. A motion picture sequence, with exposures each five seconds, was planned, but failure of the camera to arrive in Philadelphia in time to be sent off to Wolseley caused the cancellation of this part of the program. This camera was to have been used with a lens of 21 inches focal length, fed by the small coelostat of the spectrohelioscope of the Strawbridge Observatory of Haverford College.

FIGURE 1
EIGHTEEN-FOOT CAMERA IN FOREGROUND; 40-FOOT CAMERA, LEFT BACKGROUND.
(Left to right: Thomas Tiller, Town Clerk of Wolseley; Stanley Cole, Mayor of Wolseley; Roy K. Marshall, Franklin Institute; Oren C. Mohler, McMath-Hulbert Observatory; Richard M. Sutton, Haverford College.)

The natural phenomena presented for the pleasure of the visiting scientists were vivid and varied. On Friday afternoon, a brilliant rainbow display, consisting of a primary, a secondary, and many supernumeraries, was seen. On Saturday morning, a fine solar halo appeared. Saturday night, a vivid and active display of the aurora was witnessed for two hours or more; on Sunday morning, bright "sun-dogs" were observed. The mornings were usually clear, the afternoons rainy, the nights mixed cloudy and clear. The temperature remained unseasonably low during the whole stay at Wolseley.

Eclipse day dawned clear, with a streak of cloud low on the horizon from east through north to the west. The sun's rate exceeded that of the cloud, however, and the total eclipse occurred in a perfectly clear sky, under ideal conditions. With the twin 4-inch lenses of 28 inches focal length, photographs were made on 8x10 inch plates, with exposures of 30 seconds. One of these plates was 103-H, with a green filter, the other was 103-H alpha, with a red filter, thus confining the photographs to narrow regions of color centered on the green and red coronal emissions. With the 18-foot camera, one exposure of 30 seconds

duration, on a 103-B plate, with yellow filter, was made to reveal the visual appearance of the corona. With the 40-foot camera, the same plates and filter were to be used for short exposures—3 seconds, 10 seconds, 5 seconds—to show the inner corona and prominences. No plates were obtained with this long camera, due to incorrect manipulation of the slides by a volunteer. The other plates were satisfactory, although they contain blemishes and various photographic defects.

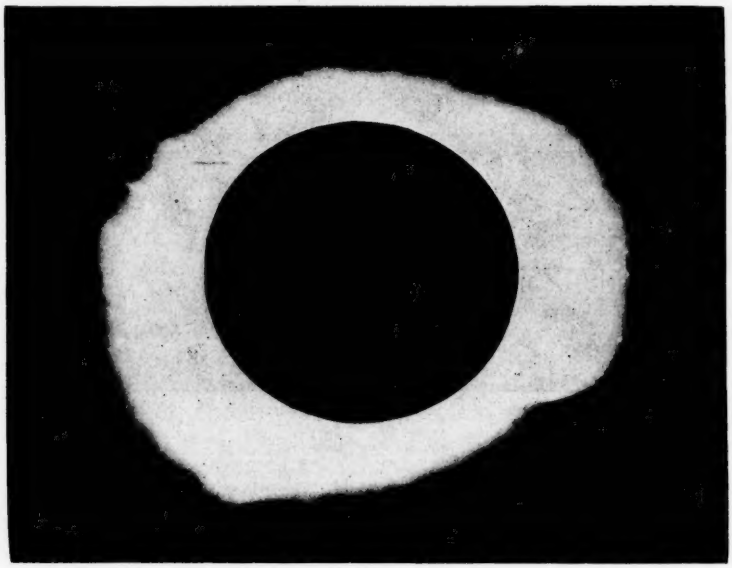

FIGURE 2

30-SECOND EXPOSURE, 18-FOOT CAMERA OF 6½ INCHES APERTURE.
Photograph by Roy K. Marshall, Philadelphia Bulletin-Franklin Institute-University of Pennsylvania Expedition, Wolseley, Saskatchewan.

Dr. Mohler loaded all plate holders and worked at the lens end of the 40-foot camera. Dr. Marshall operated the lens end of the 18-foot camera and broadcast for 20 minutes, with the total eclipse in the middle of the period. Miss Janet Anderson of Detroit pulled slides on the 18-foot camera. Dr. Sutton operated the twin 4-inch Ross-Fecker cameras. After totality, Dr. Marshall and 15-year-old Miss Anderson rushed into Regina with the plate from their camera; prints were made from it and were transmitted by Associated Press Wirephoto throughout the whole country. Another broadcast, from station CKCK in Regina, was given that evening. Dr. Sutton and Dr. Mohler began dismantling the instruments at once. Dr. Sutton left Wolseley by train; Dr. Marshall and Dr. Mohler left by car about noon on July 10, and

left Regina by plane that afternoon, arriving in Detroit and Philadelphia on July 11.

The photograph taken with the 18-foot camera (Figure 2) shows the ordinary portion of the corona very well. Visually, there was more detail than the photograph shows, and the near-minimum type of corona was more pronounced. The plates taken with the 28-inch cameras show a globular corona with an almost parallel-sided bar, running from east to west, superposed on it, the width of the bar being about a solar diameter and the extension approximately two solar diameters to each side.

To the unaided eye, three petal-shaped spikes were plainly visible; one of them pointed toward Venus, the other two eastward from the sun. The inner corona, very dazzling as compared with the extensions, surrounded the black disk of the moon out to a distance of about one-fifth of a solar diameter; no prominences were seen by Dr. Marshall, although Dr. Mohler believes that he saw prominences above the spots near the limb of the Sun. The chromosphere appeared to Dr. Marshall faintly pink, the corona a cross between creamed and pearl-white. Baily's Beads preceded totality and the Beads and a diamond-ring effect marked the ending.

The sky was very bright during the eclipse, because of the small cross-section of the shadow as it swept over Wolseley. Fine print of a newspaper could easily have been read. The shadow bands were strongly marked, at least before totality; they were very close together—perhaps three to four inches—and were making slow progress, with much flickering, in the direction south of west.

Many of the townspeople of Wolseley were present at the camp, and at the sight of the corona there were "oh's" and "ah's," clearly audible to the radio audiences in Philadelphia and Washington. At the end of totality, a spontaneous burst of applause occurred; all those who saw the spectacle were moved by it. The welcome of the citizens of Wolseley was genuinely warm; they did everything they could for the success of the expedition and made every facility available to the visitors.

If anything of a definitive nature concerning the results from the red and green photographs can be said, it is this: The globular corona appears equally strong and equally extended in both photographs, indicating that it is largely light scattered from particles surrounding the Sun, whereas the structure of the band running east and west through this globular corona is different in the two pictures, indicating the presence of ionization tracks, different for different coronal atoms. It will be at least a few weeks before study of the material is completed.

Roy K. Marshall.

Fels Planetarium of The Franklin Institute.

THE UNIVERSITY OF MINNESOTA EXPEDITION ABOVE THE CLOUDS OVER MANITOBA

Through the cooperation of Dr. Ross Gunn of the Precipitation Static Project at Wold-Chamberlin Field it became possible to observe the eclipse from a plane. Originally it had been planned to be above Lake Winnipeg during totality but, owing to heavy clouds obscuring the ground, this plan was abandoned and at the time of totality the plane was flying on a course of 343 T—so as to have the eclipsed sun directly on the starboard beam—at an altitude of 20,000 feet between Lake Manitoba and Pine River, Manitoba.

Only naked eye observations were made; since all observers were on the starboard side of the plane we missed the oncoming shadow of the moon but I saw the retreating edge of it speeding toward the northeast immediately after third contact (the shadow's ground speed was about 85 miles per minute).

The flash spectrum was clearly seen at second and third contact, and the coronal line during totality. Venus was visible all morning, Mars appeared about 10 minutes before totality, and Saturn was easily seen during totality; Mercury was not seen.

The corona which was small, appeared to be of the sunspot-minimum type, not unlike a ribbon outlined by four principal streamers; no prominences were seen.

The clouds, which were about 10,000 (?) feet below us and which had been very white before, appeared a pale, sickly greenish color during totality; clouds near the horizon remained a salmon pink. The sky took on a deep blue color but did not become as dark as expected at this altitude.

W. J. LUYTEN.

MINNEAPOLIS, MINNESOTA.

THE YERKES OBSERVATORY EXPEDITION, PINE RIVER, MANITOBA

In making plans for observing the total eclipse on July 9, 1945, Pine River, Manitoba, was selected since there was not much choice from the point of view of weather conditions west of Lake Winnipeg, and Pine River was easily accessible by car.

The writer and S. Chandrasekhar arrived in Pine River on June 30. A site commanding an unobstructed eastern view was selected the following day. According to the geodetic survey the site was 0.7 mile south of the center line.

The program was a modest one, consisting of two cameras for obtaining direct photographs of the solar corona. The six-inch UV telescope of Yerkes Observatory diaphragmed to 3 inches, was used for photographing the outermost extensions of the corona, and was operated by Chandrasekhar. One exposure of 14 seconds on Eastman 33 emulsion was made.

The second camera was one of 20 feet in focal length and 4 inches in aperture. This lens, corrected for the green and blue, was constructed by Mr. Fred Pearson in the optical shop at Yerkes Observatory in June, 1945, one month before the time of the eclipse. This camera was operated by the writer. Two exposures of 20 and 5 seconds, respectively, were made on Eastman spectroscopic II-H emulsion. Dr. Burke Smith, who had joined the party on July 6, counted seconds. Second contact occurred within a fraction of a second of the predicted time.

At sunrise on the morning of the eclipse the eastern sky was cloudy, but the drifting clouds cleared the sky about twenty-five minutes before second contact and the program was completed through a beautifully clear sky.

W. A. HILTNER.

WILLIAMS BAY, WISCONSIN.

THE NORTHWESTERN UNIVERSITY—BELOIT COLLEGE EXPEDITION, ROBLIN, MANITOBA

T. J. Bartlett and R. M. Cook of Northwestern University arrived in Roblin, Manitoba, on Thursday, July 5, and chose a site very near the center line of totality, a mile east of the Saskatchewan border and seven miles west of Roblin on the east bluff of the mile-wide Assiniboine River valley. They were joined on Saturday morning by R. C. Huffer of Beloit College.

The joint program had three objectives, namely, to determine with accuracy the times of the four contacts; to obtain drawings of the corona with special attention to the faint extensions not possible to record photographically; and to make various meteorological observations related to the shadow of the moon and its effects. We expected to be able to carry out this program because each of us had under his direction a group of loyal and delightfully competent helpers from the Roblin community. One assistant not from Roblin was C. F. Graham, of the Burnham Astronomical Society of Chicago, who arrived Sunday morning with his four-inch reflector.

Sextant and theodolite observations were begun for determination of latitude and longitude immediately upon selection of site.

Upon arising at 4:15 on the morning of the eclipse we found the eastern sky clear, but in the north and west heavy clouds were forming. By sunrise these clouds covered the entire sky except for a narrow band around much of the horizon not more than two degrees high. These clouds remained until about 10:00 a.m. We did not see the sun at any time during the entire eclipse.

The shadow phenomena were, nevertheless, interesting and even thrilling. The first sense of the presence of the shadow on the clouds came at about 12:15 G.C.T., at which time there was a very dark region to the southwest which was much more black or purple than the other

clouds. The clear area below was still a normal blue. After a lapse of perhaps 1.5 minutes the dark area had increased in size and had dropped into the clear area at the horizon. The appearance of the shadow was much like that of a very heavy thunderstorm in the distance. This changed rapidly as the general illumination faded, but almost immediately we noticed the blue sky reappearing to the southwest. We turned to the northeast, where the appearance of the sky was much the same. The sky lightened rather quickly and we all had the impression of much faster change than during the approach of the shadow. Mr. Huffer sensed that totality had ended at 12:17:54 G.C.T. This was based on general illumination for the most part, was independent of any counted seconds or precomputed time, and was only four seconds behind the expected time of third contact. Helpers in observing the shadow were Robert Graf and Gracie Starkman of Roblin who sketched the sky and wrote accounts of what they saw.

Temperature readings were carefully made over a period of nearly three hours by Joe Ellison of Roblin and showed a drop of one degree centigrade below a normal temperature curve, with a very definite minimum at the time of totality.

The eclipse at Roblin was not a dark eclipse. Indeed during totality several observers read with ease the finest newsprint to be found in the Winnipeg papers. No stars were observed, for obvious reasons.

We are deeply indebted to the citizens of Roblin who gave us invaluable help before and during the eclipse. These included Mayor Westwood, Postmaster Kines, High School Principal Stefansson, and many others who took part in our program or aided us in many ways.

R. C. Huffer.

Beloit College, Beloit, Wisconsin.

The Brackett-Mt. Wilson-Mono Observatories Expedition, Opheim, Montana

During the third term at Pomona College, in May and June, an expedition was organized at the Frank P. Brackett Observatory to observe the brief total eclipse of the sun on July 9, 1945. The path of totality in the United States was very short and crossed the Canadian border near the town of Opheim in northeastern Montana. Our station was therefore located at Opheim where it was possible to observe the course of the eclipse from the first through the fourth contacts and at the same time avoid the inconveniences of crossing the international border where only slightly more favorable circumstances could be expected. At Opheim the middle totality occurred over an hour after sunrise with the sun at an altitude of 9°.

The eclipse party was composed of eight persons and, with two exceptions, all were either students or alumni of Pomona College. The list includes Dr. Paul W. Sprague, Professor of Philosophy and Astron-

omy at Wheaton College, Norton, Mass.; Mr. Albert V. Shatzel of the Mono Observatory, Coleville, California, and his assistant, Mr. Walter Lorenz; Mr. Edwin B. Weston and Mr. H. Reeve Darling Jr., currently students in the Pomona College Astronomy Department; Miss Ruth Whitney, pictorial photographer; the writer, Professor of Astronomy at Pomona College; and his young son Richard. Six members of the party arrived in Opheim on July 4 while two came in by plane on the afternoon of July 7.

Expeditions of this nature are without exception the result of much cooperation on the part of both individuals and institutions and I take pleasure in acknowledging the invaluable assistance of members of the Mt. Wilson Observatory staff and of the Eastman Film Laboratory in Hollywood. Lack of space prevents the mention of many others who also assisted in various capacities.

The main objective of the expedition was to obtain a photograph of the corona and three telescope-cameras of focal lengths of 30 inches, 60 inches, and 15 feet were set up and fed by clock-driven coelostat mirrors. Two other short-focus cameras of 12 inches and 30 inches focal length were operated automatically with motion picture film of 16 mm and 35 mm size, respectively, to provide a record of the partial phases of the eclipse.

Through the cooperation of Mayor Bohlig and Mr. Walstad, Chairman of the Eclipse Reception Committee, and Mr. Hicks of the faculty of the Opheim High School, arrangements were soon completed for installing our equipment on the flat roof of the high school building. This proved an ideal location from every standpoint as a clear view of the unbroken horizon was obtained and the facilities of the building itself with dark room, water, and lights added greatly to the ease of establishing ourselves.

The cooperation and assistance offered us by various members of the Opheim community was a heart-warming example of the finest American tradition. One occurrence to illustrate this attitude must be related briefly.

On the eve of the eclipse on Sunday night, July 8, after supper we climbed to the roof for some last minute adjustments only to find the mainspring of one of the driving clocks had broken and burst its case wide open. Mr. Shatzel immediately undertook to make the necessary repairs and by midnight had succeeded in this only to discover that in the meantime the main spring in the other clock had broken also and taken the hairspring with it! While the others retired Mr. Darling took this second clock in hand and with the aid of Mr. Johnson, manager of the Co-op stores and local jeweler, whom he got out of bed, worked until 3:00 A.M. when finally both driving clocks were whipped into submission and functioned satisfactorily at their appointed time. For all his invaluable assistance at this critical time Mr. Johnson would only

accept a very nominal recompense. Such was the cooperation accorded us from all quarters.

Monday morning dawned with ominous skies. The sun rose before first contact from behind a bank of low-lying distant cloud and crossed a relatively clear space to be again intermittently obscured as the first partial phase advanced. At this time a cirro-stratus cloud veil provided brilliant rainbow-colored sundogs to the right and left of the narrowing crescent whose form was responsible for the unusual purity of the spectral colors displayed.

Finally as the darkness of totality approached with startling suddenness the sun cleared most of the denser cloud and the corona was readily visible through the remaining thin cloud veil. The plates from the corona cameras show the presence of the polar rays and the irregular distribution of the coronal light. Prominences were also photographed at various points around the lunar disk. Due to the swift sweep of the shadow over the earth's surface the phenomena of Baily's Beads and the chromosphere flash were difficult to note. Watching through field glasses, Dr. Sprague counted off the seconds during totality until his final shout of "Beads" concluded the corona exposures. It seems apparent from his observations at that time that the duration of totality was from one to two seconds shorter than the 31 seconds indicated by the U. S. Naval Observatory computations.

In conclusion it need only be stated that after experiencing the many trials attendant upon war-time travel over distances in excess of 3000 miles, all personnel arrived safely home though much in need of rest and relaxation.

WALTER T. WHITNEY.

THE FRANK P. BRACKETT OBSERVATORY, POMONA COLLEGE,
CLAREMONT, CALIFORNIA.

THE MILWAUKEE ASTRONOMICAL SOCIETY EXPEDITION, PINE RIVER, MANITOBA

Three separate parties from the Society went into Canada to see the total eclipse on July 9, but only one party had the good fortune of witnessing and photographing the entire spectacle.

One group headed by our president, Lawrence Peterson, went to great trouble to secure plane accommodations to fly to God's Lake. Mr. Peterson's party of six included Mrs. Peterson, Mr. and Mrs. Ernest Szekely, and Dr. and Mrs. Ross Bardell, all of whom sailed to Norway House at the northern tip of Lake Winnipeg and on the eve of the eclipse flew to God's Lake. With commendable forethought, they chose a location where the totality would last 43.5 seconds, and arranged for the plane to take them aloft in case of clouds. Thirty minutes before totality, the clouds had not broken so the pilot and three of the party attempted to fly above the clouds. Icing of the plane preventing gaining sufficient altitude so in racing for the only open spot in the clouds, the

plane left the edge of the totality path and the total eclipse was missed.

Our secretary, Herbert W. Cornell, with his usual exuberance and enthusiasm, was without question responsible for the number of Milwaukeeans who traveled north for the eclipse—our society was represented by 19 people. Mr. Cornell's enthusiasm had carried him to two eclipses without seeing one so in October, he began his plans to view this one. His party of four, including Mrs. Cornell, Dr. Ethelwyn Beckwith (her 4th eclipse), and Darrell Moore, sailed up Lake Winnipeg with Mr. Peterson's group, having chosen Sandy's Island in the center of the totality path for their post. They, too, were clouded out. Their trip was so highlighted by the courtesies and attentions of the Canadian people that they were reluctant to return home.

Pine River, Manitoba, west of Lake Winnipegosis, was chosen by the third group because of its accessibility by auto. This group, headed by Professor Edward A. Halbach of Marquette University and also Director of the Society Observatory, included C. M. Prinslow, Mrs. Prinslow and daughter, Caroline, Alfred, and Mrs. Memmel, Mrs. Halbach, and John E. Willis, on leave from the Naval Observatory. The caravan of two cars and trailer loaded with scientific equipment arrived on July 3 and its occupants set up camp within a mile of the eclipse camp site already selected by Dr. A. W. Hiltner and Dr. S. Chandrasekhar of Yerkes Observatory. Both parties used the same eclipse site because it was previously agreed that they could be of mutual assistance. In fact, this was the only good location for miles because of the swamps and second growth timber. The next six days were devoted to preparations and rehearsals: camera mountings were built, test exposures made, electric power plant and wiring installed for both parties, radio antenna masts erected and receivers set up to utilize the Bureau of Standards (WWV) time signals, and a barbed fence enclosure set up to keep out stray cattle, horses, and to discourage bears. A tent was set up for a workroom. On the morning of July 9, we were joined by E. B. Heckencamp of the society, and three men from Madison, Wisconsin, set up their telescope and cameras adjacent to our enclosure. Mr. Smith of Chicago and Yerkes joined the party as a timer.

Professor Halbach's project, which was of principal importance, consisted of a motion picture camera equipped with an f/6, 24-inch focal length objective and a 25-degree objective prism, to photograph and time the flash spectrum at second and third contacts. It was learned later that this was the only camera used on this continent in collaboration with Professor Bertil Lindblad of the Stockholn Observatory for obtaining to a greater degree of accuracy the geometry of the earth's surface, especially over the great distances between continents. The WWV time signals, accurate to better than 1/100 second were received and recorded directly on the sound track of the film and also on a chronograph. Since a knowledge of the exact geographical location of the observing station was necessary, a concrete monument was poured

below the camera and the exact latitude and longitude determined with the new Pendulum Astrolabe, designed by Mr. Willis and now in use by our armed forces. Before leaving the site the Manitoba Department of Better Roads assisted in triangulating this monument with other permanent survey monuments in the vicinity. They also spread calcium chloride on the road 300 feet east of the site to eliminate the dust hazard. Such hospitality was tendered the group not only at Pine River but throughout its stay in Canada.

Cloudy skies offered little hope at dawn on the 9th as the observing parties and the many residents assembled to witness the event. First contact was at 6:18, a break in the clouds enabled the first pictures of the partial phases to be taken at 6:30, and the rift in the clouds remained open until well after totality. Mr. Smith's counting worked to the split second, totality beginning exactly as expected; all exposures were made as rehearsed and totality was over.

Our happiness was marred only by the news that most other stations were completely blanketed by clouds.

In addition to the flash spectrum pictures made, a series of exposures of the partial phases was made with a camera of 50 inches focal length including three exposures of the corona. Another series of exposures of all phases was made with a 7-inch camera. A camera with two f/6 24-inch focal length lenses, attached to the Yerkes UV camera mounting, was used with polarized screens over the plates for simultaneous photographs to record the degree of polarization of the corona. Several other small cameras were used.

In response to a telegram to Professor Lindblad reporting success, there came the good word from Professor Lindblad, "We were successful too—." The spectrum film has not been developed and results of the program are not expected to be ready for many months. However, all other photographs taken by the Milwaukee and Yerkes parties were a success.

EDWARD A. HALBACH.

MILWAUKEE, WISCONSIN.

THE ECLIPSE OBSERVED NEAR MALTA, MONTANA

The notes from which the essential portions of this report are compiled were written within a few hours after our return to Malta from the observing station about fifteen miles south of town. It was thought best to record at least the most important details while they were still fresh in memory. My personal observations were wholly visual and were made entirely without instrumental aid, and for other reasons which will appear later, they probably do not possess a high degree of scientific importance.

On the morning of the eclipse, I arose at 2:00 A.M. and found the sky mostly clear except for a light haze just south of the zenith. About the

customary number of stars seemed to be visible at that time. At 2:30 A.M. the sky was again observed, and as far as could be seen the haze had entirely disappeared. Stars above the sunrise point were easily visible. About 2:50 A.M. a slight haze began to develop and this condition very rapidly became worse. After breakfast when we left the hotel for the observing station, which was situated near Scandia Church, Bennett Lake Community, the entire sky was more or less overcast with clouds of alto-cumulus structure, having an estimated ceiling of about 12,000 feet. This condition had not improved when we arrived at the observing station a little after 4:00 A.M. At that time there was a very heavy bank of these clouds on the eastern horizon which it seemed would be likely to obstruct the sunrise view, and, to add to our discomfort, the overcast was moving so slowly that there seemed great danger that the sky would not clear until after totality.

The calculated time of sunrise at Malta was 5:21 A.M. This time was not corrected for refraction or altitude or for change in latitude between Malta and the observing station, but at exactly this time the upper limb of the sun could barely be seen through a slight rift in the cloud formation at horizon level, but within two or three minutes it had been completely obscured by the heavier cloud formation situated at a higher angular altitude above the horizon.

The clouds were moving very slowly in a direction generally southeast and about the time of sunrise a long north-south rift commenced to develop in these clouds. The lower edge of this rift was about five or six degrees above the horizon and at the point where the sun's emergence was expected, it had an angular width of perhaps three or four degrees. The width of this cloud rift increased slightly toward the north, and the space within the rift was not obscured in any way by haze or cirrus formation and appeared to be perfectly clear.

The time of second contact or the beginning of totality for the observing station was not calculated directly, but from the data published in the Eclipse Supplement to the *American Ephemeris* this phase of the eclipse was estimated to take place at 6:15 A.M. The sun emerged into the cloud rift at 6:07 A.M., and it at once became evident that there was going to be a very close contest between the progress of the eclipse and the passing of the sun out of the rift and into the dense overcast immediately above. Fortunately, however, the sun, then about 85 per cent eclipsed, remained in perfectly clear space. The eclipse became total at 6:14:57 A.M., and the sun again became enveloped in a heavy cloud formation at 6:18 A.M. This obscuration continued with brief and unimportant interludes until the end of the eclipse.

A few minutes before the commencement of totality when the time was being called, I was observing the progress of the eclipse and was under the impression that a considerable portion of the sun's disc still remained to be covered, and indeed this impression was so strong that I almost felt that some error was being made in announcing the time.

This impression is perhaps to be attributed to inexperience in observing near total eclipses. The cusps of the exposed portion of the sun commenced to come together very rapidly and it was then that I realized that the onset of totality was at hand. I glanced in a southwestern direction toward the oncoming shadow of the moon and against a heavy cloud bank. A very distinct darkening of the sky in this region was apparent, and an instant later we were eveloped in the shadow. It was originally planned to watch the drop of the shadow and to attempt to observe the disappearance of several peaks in a mountain range about fifty miles away, but owing to the restricted visibility on the morning of the eclipse, such observations were impossible.

An instant later, I glanced in the direction of the sun and noted the "diamond ring" with a somewhat weak or subdued corona. The "diamond ring" feature disappeared in perhaps two or three seconds and the corona seemed to increase in extent and in general brightness. After enjoying the view for several seconds, I noted the sky near the horizon at situations approximately at right angles to the direction of the movement of the shadow, and noted that the color in these regions was of a light copper-like hue. I only looked at this feature for three or four seconds and then watched the eclipsed sun until immediately before the termination of totality when I turned in a southwestern direction for the purpose of observing the return of light. The sky was growing considerably brighter with the approach of the third contact, but the visibility against the heavy cloud formation was very poor, and I am not certain that I was able to note the precise moment of light return. I was much interested in the "diamond ring" phenomenon and the solar corona, so I almost immediately returned my attention to the sun and was fortunate in being able to observe the "diamond ring" at third contact and the final disappearance of the corona a few seconds later.

It might be added that some few minutes before the eclipse became total, the general landscape and all visible objects commenced to take on a subdued greenish or greyish hue which became more pronounced and apparent as the total phase approached.

The corona seemed to me to be of a light pearly color, perhaps not entirely uniform throughout. Its structure as noted at the time and as remembered consisted of short filaments surrounding the edge of the sun with four long coronal streamers extending radially to what seemed to be one or more solar diameters. These streamers were roughly triangular with the bases of the triangles at the sun. The lower streamers were appreciably the longer, and they were placed around the sun with approximate symmetry. My memory is that these coronal streamers were sensibly straight, and that they showed no appreciable curvature, but I may be mistaken at this point as I did not look particularly for this feature of the coronal structure. So far as I observed, there was a complete obsence of prominences, and I am wondering whether prominences were seen by other observers.

Having never previously witnessed a total solar eclipse, I was somewhat overcome with the beauty and grandeur of the spectacle, and may possibly have missed certain details which should have been noted.

WILLIAM D. MORGAN.

ST. PAUL, MINNESOTA, JULY 14, 1945.

OBSERVATIONS FROM THE AIR NEAR MALTA, MONTANA

5:10 A.M.—We took off. The sky looked very unfavorable, but we had hopes of getting above the clouds. Our course was about 65° true at a steady climb and we arrived over Saco at 5:48 A.M. with an altitude of 7500 feet. We had 12 minutes to go before we started our run, so we circled over Saco until 6:00 A.M. and gained an altitude of about 8500 feet. We then took a course of about 150° true in a climb for 10 minutes at an air speed of just over 70 miles per hour.

6:10—We gave up all hopes of seeing total eclipse because of a cloud bank to the east, so we began jockeying for position for photographing the approach of the shadow. The ground haze extended to about 5000 feet, and was very thin but it made it impossible to establish a definite horizon, or to see the ground to any extent except in a small radius directly below us. Our altitude was now slightly less than 9000 feet although an accurate reading was not made. Long and very white horizontal clouds to the west extended about 20° covering the direction of the approach of the shadow.

6:11—It was getting very dark. My meter reading was 6.5. We were now guiding on a cloud with a distinct formation at about 185° true.

6:12—The upper edge of the cloud bank to the east began to scatter, and our hopes again rose that we might be able to see totality. The clouds to the west were getting very dark, but we could see no evidence of the advancing shadow. All light seen in shadow or in rays was remarkably white, except for the very ruddy horizon along the path of totality to the northeast. It looked as though there might be good seeing between Opheim and a point about 25 miles from us. Our visibility was perhaps 50 miles toward the sun and about the same along the line of totality back to the southwest, but no distinctive features could be distinguished for we were sandwiched between two cloud layers.

6:14—There was about one minute to go, so I gave the pilot, Harold Ebaugh, the meter reading which had now dropped to 3.2; and since he had faster film he began shooting in the direction of the approach of the shadow as soon as we could get the windows down. The temperature had dropped to between an estimated 0 and 10° F. and my hands were cold and slow. I could also just begin to feel the lack of oxygen. All this added to the excitement, and curiousity made my movements less accurate than they might have been under normal conditions.

6:14:30—Between shots we could see the shadow coming at a terrific speed, but still could find no definite outline, which was probably due

to the fact that there were no clouds on which we could locate its position in relation to the ground. I happened to notice that the white cloud along the horizon had grown much larger and everything in the west was a dirty gray. I took one last look at the meter, but it did not register appreciably.

6:15:05—Our approximate position was: Latitude 48° 22′ north, Longitude 107° 17′ west. We just flew around the bank of a cloud in time to see the disappearance of the diamond ring. The sky was very clear and blue in the break, and the corona was a very silvery white hue with what seemed to be curving rays in the line of the magnetic field. I took one shot of it, then turned around again to take one more of the approaching shadow. In this split second the horizon to the west and clouds above us became extremely dark, and the meter showed no suggestion of registering; there seemed to be much more haze in the direction southwest along the central line. I took two shots with the camera wide open, and I happened to look down just in time to see the recession of the shadow on the ground below us, which must have taken about ⅕ of a second to pass our visible range on the ground. It was quite easy to detect a definite elliptical curve on the ground. At that instant we turned and began shooting the shadow along the central lines to the northeast, but it soon disappeared into indefiniteness in the haze.

6:16—Things were rapidly becoming lighter all around us, and we noticed a very white cloud formation directly below us, which we suddenly realized was a vapor trail left by the change of temperature during the passing of the shadow. There was no definite surface visible until one looked back along the central line. The trail left was not exactly straight, but there was no doubt as to what caused it, for it followed the path almost exactly. It was perhaps 15 miles wide and 300-500 feet thick, and extended back as far as the eye could see. Our altitude was still about 9000 feet, and the trail must have been about 6000 feet.

6:16:30—We made an extremely sharp bank to the left and we were just in time to see the vapor trail advancing along the central line to the northeast. It was already about two miles away and moving slowly and more irregularly which was possibly caused by a warm body of air east-southeast of Saco over the Milk River. We took three or four shots but the light was still bad.

6:18—The sun disappeared behind clouds again and we could no longer follow the vapor trail in the distance so we made a 180° turn and headed for the eclipse site. A glance below showed a beautiful rainbow ring on the vapor trail which had a dark crescent in the center. My first impression was that it was an after image of the sun, but I noticed that the crescent was reversed so I asked the pilot and he also noticed it. He put the plane in a vertical dive for 1500 feet and we pulled out noticing that the shadow was half crescent and half plane; then as we descended farther it became a perfect shadow of the plane; which confirmed our estimate of being 3000 feet above the vapor trail.

We noticed the remarkably white quality of the light forming the ring.

6:20—The pilot wanted to get down below the clouds before he got lost, so he put the plane in another vertical dive for another 3000 feet, and we followed a creek from the Benjamin River until we hit the eclipse site. We circled a few times and not finding a place to land headed back to Malta and landed at 7:20 a.m.

EQUIPMENT

1 Bantam Special F-2
1 Perfex F-35
1 Weston Master Exposure Meter.

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The Study of Stellar Variation*

By DEAN B. McLAUGHLIN

INTRODUCTION

Variable stars are a challenging phenomenon, a curiosity of the sky, in striking contrast to the majority of stars that remain apparently unwavering in their light. Perhaps, if they were rigorously tested, most stars would be found to vary a few thousandths of a magnitude, but it is a far cry from such changes to the violent flarings of SS Cygni or the somewhat slower but no less spectacular variations of Mira. Ultimately we wish to understand these objects. From this point of view, the study of stellar variation is of interest in and for itself.

But it is not possible to divorce variable star astronomy from the broader astronomical field. To understand variables, we must know something of the geometry, chemistry, and physics of the constant stars. The variables may even help us to understand better the unchanging ones. The study of stellar interiors can be expected to profit from increased knowledge of variable stars, and the study of variables as such will benefit in turn from advances in theoretical studies of the inaccessible centers of typical constant stars.

Variable stars are now indispensable tools for the measurement of vast distances in the galaxy and the metagalaxy, and in the study of motions within our stellar system. So far, the Cepheids have been the most useful, but the novae have supplemented them. In the future, other types of variables may be expected to come into greater use. Conversely, increased knowledge of the structure and internal motions of the galaxy and of external galaxies can lead to otherwise unattainable knowledge of variables. This is particularly true of determinations of absolute magnitudes.

It is not possible to give here a comprehensive treatment of stellar variation. At best we can review the field in a general way, discuss the development and present status of a few selected divisions of it, attempt

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to correlate facts and theories in these "selected areas," and note some of the more obvious problems that are in greatest need of attention. It is hoped that the discussion will be suggestive and thought-provoking, rather than conclusive.

We shall further limit the scope of discussion to a loosely defined period of fifty years, essentially 1892 to 1942 (the latter date marks a temporary decline of pure research) but we shall take cognizance of important publications up to 1945 inclusive.

Two important types of variables will receive only scant notice. The eclipsing binaries, because they are not true variables, will be discussed only in so far as they are either intrinsically variable or subject to unusual physical effects different from those of the classical eclipse of one sharply bounded spheroidal star by another. The novae also will be largely omitted, since the writer has already presented in this journal several aspects of the nova problem, and hopes to discuss others in the future. Otherwise the novae would be entitled to a large allotment of space, for a rigorous line of demarcation between novae and *bona fide* recurrent variables simply does not exist.

Indices of Progress

The great progress in fifty years is superficially evident in a comparison of catalogs of variables. Chandler's catalog[1] of 1893 contained 260 variables. By contrast, Schneller's catalog for 1941 listed 8445 stars. Besides these, there are thousands of known variables in globular clusters and in the Magellanic Clouds, as well as many others not listed by Schneller, so that the total number known now is probably close to 20,000.

Numbers, however, do not necessarily indicate progress in understanding. Let us look, then, at the schemes of classification in use at the beginning and end of the period. In 1881 Pickering[2] published a classification that endured for nearly 30 years. Five types were recognized, as follows:

1. Novae
2. Long-period variables, such as o Ceti.
3. Irregular variables.
4. Short-period variables, for example, δ Cephei and β Lyrae.
5. Algol variables.

Especially noteworthy is the inclusion of β Lyrae with δ Cephei instead of with Algol. In 1911, however, Pickering[3] revised the groups and rectified this defect. But for a number of years the U Geminorum variables and R Coronae stars were treated as a sub-class of long-period variables. To us today it is incongruous, but at that time nothing was known of the spectra of these rarer types.

The recent (1938) classification by Payne-Gaposchkin and Gaposchkin[4] may be summarized briefly as follows:

a. Geometric variables (eclipsing and ellipsoidal).
b. The "Great Sequence": long-period, semi-regular, Cepheid, cluster-type, and irregular red variables.
c. Cataclysmic variables: Novae, U Geminorum stars and R Coronae Borealis stars.
d. Extrinsic or nebular variables.

Of necessity, Pickering's classification reflected a knowledge of a somewhat superficial characteristic, the light curve. Fundamental as this is, by itself it tells little of the physical processes in variables. It requires supplementary information that was almost nonexistent fifty years ago. The Gaposchkin classification, on the other hand, reflects a certain understanding of the physical nature of the variations, and at least some suggestion of the basic mechanisms.

In the years between 1911 and 1938 several different schemes were proposed. All of these recognized the Pickering types, but the irregular and semi-regular variables were evidently a "headache" (they still are!) for we find them split up in different ways by each different classifier. Such closely related objects as R Sagittae and R Scuti were sometimes separated, and such unlike stars as μ Cephei and R Coronae were grouped together. It is a little amazing to note that the first serious proposal that SS Cygni might be closely related to novae was based, not alone upon the obviously nova-like character of its outbursts, but upon its spectrum.[5]

Techniques

At the beginning of our fifty-year period the application of photography to the continuous recording of the sky was just beginning. Until then, practically all variables were discovered visually and by accident. Today the discovery proceeds at a rate of hundreds per year, practically all found on photographs as the result of a concerted plan for discovery.

During five decades precise techniques of photographic photometry have been developed. The extra-focal method gives accurate light curves of single variables that are surpassed only by observations made with the photoelectric cell. That the extra-focal method is not more extensively used is probably due in large part to the fact that plates so taken are not particularly useful for any other purpose, and the limited magnitude range that can be investigated on a given extra-focal plate is a serious drawback. In the long run, plates taken in focus and with single exposures pay the greatest dividends in the general broad study of variables.

The photoelectric method has been developed to an accuracy of a few thousandths of a magnitude. On a telescope of very modest dimensions and with a suitable amplifier, a photoelectric photometer can now be applied to variables fainter than the ninth magnitude, though it appears likely that it will be of greatest value in the heterochromatic precise photometry of the brighter variables.

Of great importance in the extension of physical knowledge of the red variables has been the development of vacuum thermocouples. Pettit and Nicholson have given us measurements that embrace practically all the stellar radiation that comes through the earth's atmosphere. These observations are especially valuable for determinations of temperatures.

It is remarkable that there is no really modern method of getting numerous observations of the magnitudes of long-period variables. Today, as fifty years ago, we are still largely dependent on visual estimates, in spite of the obvious troubles caused by color equation when observing these red stars. More precise light curves would result if steps were taken to reduce the scatter that is due to subjective effects. If a simple, inexpensive device were invented, which could be a part of every amateur's equipment and which would make observations more objective, the value of the amateur's observations would be correspondingly increased. If the number of observations were cut in half, but the errors also cut in half, the resulting mass of data would be twice as valuable, according to the theory of errors.

Spectroscopic studies have been legion—both general studies of spectral changes of stars as a class and detailed records of the spectra and radial velocities of selected typical objects. The general characteristics of the spectra and velocity variations of the main types of variables are now established, and rather precise knowledge is available in some cases.

The motions of variables have been used to derive mean parallaxes and mean absolute magnitudes. Knowledge of the more numerous types of variables is in a fairly satisfactory state in this respect. There remain some gaps that will not be filled until more members of the classes are known. Thus, information on the luminosities of U Geminorum stars and R Coronae stars is still in a rather crude state.

All types of observation and discussion contribute to the general picture of physical processes that eventually serves as the basis for a comprehensive theory of stellar variation. One technique of recent development is spectrophotometry. It is difficult now to see which holds the greater promise: six-color photometry with photo-cells, or recording thermocouple photometry of photographed spectra. In so far as spectral line intensities are concerned, the latter is the only feasible technique, but the former bids fair to excel it in the measurement of energy distribution in the continuum. To date, spectrophotometric investigations of variable stars have been isolated special studies of individual stars by individual observers, with very diverse equipment and techniques, and sometimes with rather contradictory results. This is inevitable in a newly developing field. In the course of time the techniques will become stabilized and the contradictions resolved. To this end, instrumentation designed to eliminate laborious reductions and computations will be invaluable. The direct-intensity microphotometer[6] is an example of such a development.

Observational astronomy is often in danger of lapsing into the Baconian fallacy of making numerous uncontrolled and uncorrelated observations in the hope that, by collecting and tabulating the data, we may discover the laws of nature through an almost mechanical procedure. True, we have never had too many observations, but in retrospect we can see how it should have been obvious that carefully planned programs of coordinated observations of different kinds would have yielded results more quickly and with less expenditure of effort. As an example, there has been a noteworthy lack of simultaneous or coordinated photometric and spectroscopic observations. The observer of the light curves may even know or care little or nothing about the spectra, and the spectroscopic observer almost always has simply awaited the publication of light curves, or else published his work to be correlated with the light curve by others who followed. One observatory, or two working in concert, could have made coordinated studies, but only in a few isolated instances was any such program attempted.

For the future, it appears that the selection and intensive observation of a few typical objects of each class is likely to advance our knowledge of stellar variation most efficiently. This does not mean that the general following of numerous variables is unnecessary; on the contrary, we shall need as much of this routine as ever. But it needs to be supplemented by really determined and coordinated attack, from all possible directions and with the most powerful weapons available, upon the most accessible truly typical variables.

It is, however, somewhat difficult to see how the known techniques of observation alone will lead much farther in the understanding of, for example, δ Cephei. Greater precision may be and should be attained, but increase of precision does not necessarily mean greater knowledge or better understanding. More and more it is becoming evident that the greatest need is for new *ideas* for the interpretation of existing data, or ideas that will suggest further specialized observations by the known techniques. More visionary, perhaps, is the hope that a totally new technique, as revolutionary as was spectroscopy, will become available. To the positivist philosopher, Auguste Comte, it was self-evident that we should never know the chemistry of the heavenly bodies! The new technique may be just as inconceivable to us now, as was spectroscopy to Comte. Only recently "cosmic static" on a frequency of 160 megacycles has been detected[7] and found to have maxima in the bright star clouds of the Milky Way. There is no telling what might come of an exploration of higher frequencies.

Eclipsing Binaries

In 1889 Vogel observed the radial velocity of Algol before and after eclipse, and thereby proved the eclipse theory. From that date until 1934, the simple model of two spheroidal stars with sharp boundaries and atmospheres of negligible extent sufficed to account for almost all

the observed phenomena of eclipsing binaries. Beta Lyrae presented some remarkable spectroscopic anomalies, but even in that case the spectrum of its primary star was well-defined and gave a velocity curve without appreciable peculiarities.

In 1934, for the first time, the structure of a stellar atmosphere was observed directly. The relatively small early-type component of ζ Aurigae,[8] during its passage behind the extensive atmosphere of its enormous companion, revealed the distribution of atoms of different elements in that atmosphere. Strange anomalies in the spectrum of ϵ Aurigae[9] were next explained in similar terms, with the addition of an induced partial opacity of the atmosphere due to ionizing radiation of the bright star. VV Cephei[10] gave another example of an extensive atmosphere and a still incompletely explained envelope spectrum. Both ϵ Aurigae and VV Cephei are subject to intrinsic variation of small range, in addition to their eclipses. Next the anomalies of the spectrum of β Lyrae[11] were attributed to gaseous currents which appeared projected upon the primary star at certain phases, and to an expanding gaseous envelope about the system.

In all the above examples the velocity curves "made sense" and it was still possible to consider the stars as essentially sharp-edged, though it was suggested that VV Cephei might not be sharply bounded. A few incompletely observed stars, however, showed very anomalous velocity variations. It was not until 1943 that a concerted attack on these objects broke them down.

The best example is SX Cassiopeiae,[12] whose velocity curve is subject to a serious distortion. Struve reasons from the analogies with β Lyrae that this is due to the interposition, between the observer and the primary star, of a stream of gas which serves as a source of absorption and masks the true radial velocity of the star at certain phases. Similar effects were detected in RX Cassiopeiae.[13] A third case is U Cephei, a problem of long standing, for Carpenter[14] found some years ago that its velocity curve demanded a very eccentric orbit, though the light curve indicated a circular one. The distortion of the curve is similar to that of SX Cassiopeiae, and Struve[15] suggests the same interpretation. In β Lyrae the stellar spectrum and that of the gaseous stream are separable on the basis of composition or velocity or both. In these other stars both velocity and composition differ insufficiently to permit separation, with resulting blending and superposition of lines and bad distortion of the velocity curves.

Additional effects in SX and RX Cassiopeiae are the radical difference of duration of eclipse phases in different wave-lengths of light.[16] This apparently means that the radius of the eclipsed star is smaller in photographic than in visual light. The differences go beyond what could be expected from different degrees of darkening of the limb in the two spectral regions, and it has been proposed[17] that the explanation lies in actual diffuseness of the stellar limbs. Possible alternative ex-

planations must be sought and thoroughly examined, but it is *a priori* reasonable that just these stars should be so constructed. Both RX and SX Cassiopeiae are giants and are intrinsically variable through a small range.

The eclipsing star W Serpentis is even more strange.[18] In this system it is concluded that the velocity curve simply represents the motions of gases in an extended shell surrounding the system.

Now that the peculiar effects have been recognized, we may expect them to be found in some of the better-behaved binaries in which they are not prominent. The writer recalls anomalies in Algol and in λ Tauri. In the investigation of all such cases, intensive series of coordinated precise photometric and spectroscopic observations are needed.

The Cepheids

At the beginning of our half-century only a couple of dozen Cepheid variables were known—all of "classical" type (period over one day). What with the lack of uniform standards of magnitude for comparison stars and the inevitable errors of visual estimates, the forms of some of the light curves were (by modern standards) pretty crude. Even such a bright and well-observed star as η Aquilae masqueraded for many years as one of the group that have a very marked secondary maximum. Possibly we shall never know whether the second maximum was really as strong as it was depicted, but the invariability of the curve in later years is unfavorable to the view of radical change. Modern precise photometry has given many excellent light curves of Cepheids.

No cluster variables (period under one day) were known at all at the beginning of the fifty years. Soon, however (1895), great numbers were found in the globular cluster ω Centauri, and Bailey's paper on these stars is a classic.[19] Soon "cluster variables" were found outside of globular clusters, all over the sky. The first (and still the brightest one known) was RR Lyrae. The very rapid brightening and rather fast decline of many of these stars, together with the long and nearly flat minimum, suggested the term "Antalgol" which enjoyed popularity for a time, but now it has sunk into well-deserved oblivion.

In 1891 the first studies of stellar radial velocity by modern photographic methods were just beginning. The first Cepheid velocity curve and "orbit" was published by Belopolsky[20] for δ Cephei. It was a matter for surprise that the minimum of light did not come at the middle of the velocity range as it should if the star were an eclipsing binary. Before the turn of the century, precise velocity curves for η Aquilae had been determined by Belopolsky[21] and by Wright.[22] The relation of light and velocity curves was the same as in δ Cephei: maximum light at minimum velocity, minimum light at maximum velocity. Since then, numerous velocity curves have shown that this relation is universal but not precise. With lengthening period, there is a tendency for the velocity minimum to come somewhat later than light maximum.[23]

In 1923, at the University of Michigan, it was found that different sets of lines gave different velocity curves.[24] The hydrogen lines reach maximum and minimum velocity distinctly later than do the metallic lines in general, and metallic lines characteristic of the solar chromosphere also lag behind the low-level lines, but not so much as do those of hydrogen. The significance of these observations will be discussed in the section on "The Pulsation Theory."

With increase in the precision of observation, phenomena which at first appear simple are revealed as increasingly complex. We can no longer speak of *the* light curve of a Cepheid but only of its light curve for a specific wave-length region. Recently published six-color curves for δ Cephei by Stebbins[25] show that the time of maximum is progressively later for longer wave-lengths and that, in accordance with this effect, if we choose equal magnitudes (for any wave-length) on the ascending and descending branches of the light curve, the star is bluer during the increase of light. Spectrophotometric work by Norman[26] indicates a similar and very marked effect in RR Lyrae and a less conspicuous difference in SU Cassiopeiae. The problem appears even more complicated when the spectral class is introduced. We have been in the habit of expecting color to show a one-to-one relation to spectrum in a given star. But while RR Lyrae has an earlier spectrum at a given magnitude during the increase of light than during the decline (in agreement with the color difference), SU Cassiopeiae has a later spectrum during the increase. Effects of this sort need further study; perhaps our spectral criteria are in need of improvement.

The classification of Cepheid spectra has presented some contradictory results in past years. On the one hand, the Harvard classifications, in accord with Shapley's earlier work[27] at Mount Wilson (with objective prism spectra) show a range of a full class between maximum and minimum light, while the Mount Wilson classifications made on slit spectrograms show a somewhat smaller range, even when main emphasis is placed on the hydrogen lines, as in the Harvard work. The metallic lines, according to Mount Wilson, have a very small variation, only one or two tenths of a class.[28] The question as to which method gives the correct spectral class is a complicated one, but the range indicated by hydrogen is in good agreement with the large change of color from maximum to minimum. Whatever criteria are used, they should be uniform for all stars and should be tested for systematic differences as a function of dispersion.

The character of the possible systematic effects that depend on dispersion or purity can be demonstrated by a simple experiment. If spectra of a Cepheid at maximum and minimum are taken with a slit spectrograph with dispersion 40 A/mm, and compared under a microscope magnifying about 15 times, the differences are not particularly striking. Even the hydrogen lines do not seem to show remarkable differences. But when the same two spectrograms are viewed with the

unaided eye, the change of the hydrogen lines is remarkably conspicuous. The unaided eye integrates the core and wings of the hydrogen lines, while under magnification the effect of the wings (where the largest variations occur) is lost. A similar effect would operate in slitless spectra as compared with slit spectra, or in low dispersion versus high dispersion.

Recently Struve[29] has pointed out that Cepheids at *minimum* have spectra very like those of normal supergiants. At maximum they are decidedly abnormal; the hydrogen lines are much too strong for the rest of the spectrum, and thus indicate a much earlier type; the lines of Tiii also are abnormally strong. Struve recommends that the spectral classes at minimum be used for statistical purposes.

Space does not permit more detailed examination of the spectral changes and variations of color temperature of Cepheids. Valuable spectrophotometric work has been done by Whipple,[30] but much more is needed. An important program would be an intensive study of several Cepheids by means of uniform criteria and techniques. Simultaneous observations should be made of light curves, variations of velocity, changes of the line spectrum and color temperature.

The variation of light curves and periods of Cepheids will absorb a good deal of attention on the part of students of variables for years to come. There is no substitute for time. So many claims of variable light curves have failed of confirmation when really precise observations were made that the general opinion on this subject is perhaps hypercritical at the present time. Some changes cannot be doubted. RR Lyrae and AR Herculis, both cluster variables, show periodic changes of curve form. TU Cassiopeiae and BF Ophiuchi are subject to changes, and others could be listed. On the other hand, our old friends δ Cephei and η Aquilae have shown perfect repetition since precise photometry has been applied to them.

Changes of period are unquestionable among cluster variables. This may be, indeed, the rule rather than the exception among the variables in globular clusters. Period changes of classical Cepheids, though definite in some cases, are smaller and are conclusively established in relatively few stars.

The subdivision of the Cepheids into five groups[31] which overlap at the ends of the period range of each group needs to be examined in detail on the basis of velocity variations, spectral class and any other observable characteristics. So far it depends entirely upon the progression of forms of the light curves. The faintness of some of the variables at crucial points in the sequence of periods will make such tests difficult. It may even be necessary to enlist the aid of the 200-inch telescope.

The discussion of other very important aspects of Cepheid variation will be included in later sections on "Characteristics of the Great Sequence" and "Pulsation Theory."

The Mira Family

The long-period variables were already known in considerable numbers at the beginning of our fifty-year period. Their large ranges of magnitude made them easier to discover than any other type of variable except novae, and their red color and distinctive spectrum made them easy to classify, once these characteristics were recognized as the badges of long-period variability.

Some years ago it was the fashion to attempt to represent light curves by mathematical expressions and to attempt to attach significance to coefficients of the terms. Such representations have led to almost no progress at all. About the only thing they proved was the similarity of curves whose resemblance was already obvious to the eye, without the labor of a Fourier analysis.

Campbell[32] and Ludendorff[33] have defined subclasses on the basis of form of the light curves. For our present purpose only three groups need be considered. In Ludendorff's terminology, these are: the α-type, unsymmetrical curves with the rise steeper than the decline; the β-type, symmetrical curves; and the γ-type, curves with a pause or inflection on the rising branch, or sometimes with a minor maximum.

The distribution of these curve forms is rather systematic with respect to length of period, but it is most curious that the relation of curve form to period is different in the different spectral classes. Thus, among the Me stars, the symmetrical β-curves appear only among those of shorter period, and the degree of asymmetry of the α-curves increases with increasing period. On the other hand, among the Se stars or the R and N variables, the symmetrical β-curves occur in variables of quite *long* period, and indeed the majority of variables of these less common types have curves of the β form. Curves of γ-type seem to occur for nearly all periods among Me stars, though a minimum of frequency occurs about a period of 300 days.

Such a systematic relation demands a physical explanation. In casting about for a common characteristic of all the variables with a given form of curve, we note that, since there is a period-spectrum relation, the short-period Me stars have much weaker TiO bands than do those of longer period, and of course Se, R, and N stars have no TiO bands. Is it possible that the strong asymmetry of the light curves of Me stars of longer period is in some way related to strong TiO bands? Or is greater visual range of variation the determining factor?

The radiometric measures by Pettit and Nicholson[34] and the infrared photographic observations by Hetzler[35] show unmistakably that the maximum of light in the near and the more distant infrared occurs progressively later than the maximum of visual light. A similar effect in δ Cephei was noted in the preceding section. The brightest Mira stars, then, like the Cepheids, are bluer on the rising branch of the light curve than at the same magnitudes during the decline. A similar effect was suspected by the writer in the spectrum of R Scuti and was con-

firmed by photometric studies on Harvard plates.[36] This seems to be a common characteristic of stars of the "Great Sequence." But we may well raise the question whether the color asymmetry is equally conspicuous in stars with both symmetrical and unsymmetrical light curves. Evidently much work remains to be done. Spectrophotometry would answer some of the questions better than would light curves in different wave-lengths. In particular, the light variation in different spectral regions must be accurately partitioned between the continuous spectrum itself and the overlying absorption bands of TiO. The estimate by Joy that two magnitudes of the visual variation of Mira are due to variation of TiO does not appear excessive. Scott[37] has pioneered in spectrophotometry of Mira. He finds that the light variation is completely accounted for by variation of temperature and by line and band absorption. There is no room left for "veiling" or non-selective absorption (which would make the range of magnitude greater than that computed from changes of temperature and selective absorption).

Owing to the extreme faintness at minimum, the spectral changes of long-period variables long remained very imperfectly observed. Stebbins[38] followed the spectrum of *o* Ceti from maximum to minimum in 1902-1903, but it was not until 1919 that a general description of the spectral changes of long-period variables as a class was given by Miss Cannon.[39] Soon after, Merrill[40] outlined the changes of the emission lines throughout the cycle of a typical Me variable. A later and more precise discussion[41] included more variables, some of class Se, and showed striking differences of behavior between the bright lines in Se and Me stars. In the meantime, a thorough study of the spectrum of *o* Ceti by Joy[42] gave the first complete record of the absorption spectrum and the first radial velocity curves for a star of class Me.

The spectral changes of *o* Ceti are fairly typical of the class. At maximum the spectrum is M5; at minimum it is M9. The difference appears chiefly in the enormous intensification of the TiO bands at minimum, along with a great strengthening and broadening of the line 4227 Ca I, and similar but less extreme intensification of lines of Cr I. Numerous fainter absorption lines arising from excited atomic states disappear at minimum. These changes are accordant with the variation of temperature from 2000° K at minimum to 2900° K at maximum, indicated by the radiometric measures.

The emission lines of hydrogen appear shortly after light minimum. At first Hδ is much stronger than Hγ and Hβ is usually invisible. The lines strengthen together, Hγ gaining on Hδ but remaining the weaker. Shortly before maximum the ratio levels off and remains constant until some weeks after. As the light declines, the bright lines all weaken, but presently Hδ begins to fade more rapidly, so that Hγ becomes the stronger. At an extraordinarily bright maximum, Hγ may surpass Hδ before maximum is reached. On such occasions Hβ is conspicuous. Now it is noteworthy that Hβ is in a very heavy absorption band, and

Hγ is in a weaker one. The greater strength of Hγ and Hβ at brighter maxima is related to the weakness of TiO on such occasions, and suggests that the absorption occurs at a higher atmospheric level than the emission. The extreme faintness of Hε is similarly explained by overlying CaII absorption.

Emission lines of FeII and SiI become conspicuous at and near maximum light, and, as the light declines, emissions at 4202 FeI, 4308 FeI, and lastly 4571 MgI successively strengthen and fade away. The last line endures even a little after minimum light.

The changes in the Se spectra are somewhat different. There the hydrogen emissions have their normal order of strength, Hβ the strongest, Hγ next, and Hδ next. As maximum is approached they all strengthen, but Hδ increases relatively to the others, though it remains weaker than Hγ. As the light fades Hδ declines relatively. Here the change looks very much like what we should expect from increasing and decreasing excitation as the star brightens and fades.

This difference between the behavior of the emissions in Se and Me spectra must be explained by any theory of long-period variation. It is perhaps a superficial view, but it is worth considering that the changes in class Se are a pure excitation phenomenon, while in class Me they represent a conflict of changing excitation and variable TiO absorption, probably modified by changes of position of the effective emitting levels relatively to the absorbing layers.

Only a few long-period variables have been observed for velocity of the absorption spectrum through the complete cycle. Mira seems to be typical, with velocity maximum at light maximum, velocity minimum at light minimum, just the opposite of the well-known Cepheid correlation. The emission lines, however, vary in a totally different manner, with a velocity minimum some weeks after light maximum and velocity maximum near light minimum. The absorption and emission curves do not cross but just merge at the maximum of the emission velocity. Thus, relatively to the absorption, the emission always has a velocity of approach. A possible meaning of this displacement will be discussed in the section on "Pulsation Theory."

Other long-period variables differ in details. In R Virginis[43] the absorption velocity maximum precedes light maximum, and the velocity curves of emission and absorption do cross. In several other variables, numerous observations show a minimum of the emission line velocity shortly after light maximum.

The difference between emission and absorption velocities is correlated with period of variation;[44] it increases from 0 for periods near 100 days to 20 km/sec for periods about 450 days, except for a fluctuation near a period of 250 days. These measures, of course, refer to phases near maximum light, when the absorption spectrum is strong and the emissions have very nearly their greatest shift toward the violet relatively to the absorption spectrum.

Foremost among the problems requiring solution is that of the origin of the emission lines. Scott finds that the relative strengths after correction for TiO absorption are those to be expected at an electron temperature of 20,000° K. Is there a "window" in the opacity spectrum of the stellar material that permits the leakage of ultraviolet radiation from the layers beneath the photosphere? Do the hydrogen atoms suffer collisions with high-speed electrons emitted in some unknown way from the photosphere? Or does the excitation energy come from some other collisional process, for instance collisions with TiO molecules? Does the association of a faint hot companion with Mira have anything to do with its variation and with the excitation of the emission lines? For that matter, how many long-period variables have unrecognized faint hot companion stars? So far we know only o Ceti and R Aquarii, but if we spread our nets to include red irregular variables, the haul includes several very peculiar objects with composite spectra, giant M-type stars with high excitation emission spectra (including lines of HeII) and faint early-type continuous spectra extending far into the violet. Examples are RW Hydrae and AX Persei, and we could go on and cite nova-like variables (Z Andromedae) and true novae (T Coronae Borealis) with giant class M companions. The number of cases of such association of hot stars with giant M stars and high-excitation emission spectra is altogether too great to be explained in terms of mere accidental association or selective discovery.

The bright lines in Mira have been observed as double or triple on occasions. Is this due to overlying absorption, or are the lines inherently triple? The answer would require observations to determine whether the division between components shifted with the absorption spectrum. the intensity anomalies are satisfactorily explained by overlying absorption.

If we are to understand the physical significance of the α-, β-, and γ-type light curves, we must have records of the spectral changes, radial velocities and spectrophotometric data on some typical stars in each group. Possibly the data already exist, in part, in a raw state, but certainly no comparative discussion has been presented. Thus, we may ask in vain: how do the emission changes differ in the spectra of stars with α-curves as contrasted with β- or γ-curves? What happens in the spectrum at the pause on the rising branch of a γ-curve? Possibly the difference, if any, will have a doubtful significance on account of the vast extent of atmosphere involved; as Merrill says: "because of the large size of these stars or the low densities of their atmospheres, or for other reasons, various spectroscopic phenomena are not closely interrelated but may proceed in partial independence of each other."[45]

If we had the really detailed record of just one good example of each type we would have something to start with—something to suggest further lines of attack. Perhaps this is a problem for the 200-inch tele-

scope, unless some technique can be devised that will push the limit of the 100-inch fainter.

The Semi-Regular Variables

Best known among the semi-regular variables are the RV Tauri stars[46] with their quasi-Beta Lyrae light curves that vary in form, sometimes degenerating temporarily into Cepheid-like curves and at other times lapsing into variation of reduced range or less regular form. The interchanges of minima, the deeper of the two becoming shallow and the shallower one becoming deep with little or no warning, and their rather marked changes of period are additional characteristics. Their spectra are very similar to those of Cepheid variables of rather long period, and some of them show bands of TiO at minimum, in an absorption spectrum that is much too early to have TiO bands! The periods of the Beta Lyrae-like variations fall in the gap between Cepheids and long-period variables.

Like the light curves, the velocity curves are variable in form, and in those stars which have variable range of light, the velocity range is correlated with that of the magnitude curve. R Scuti is the least regular member of the class, and is therefore an excellent example of such behavior.[47] The velocity curves of these stars have a rather well-marked characteristic form, of which that of AC Herculis[48] is typical, and the relation of the light and velocity curves is not precisely Cepheid-like.[49] A deep minimum of velocity precedes the decline of light into the deeper minimum; the highest maximum of velocity occurs during the increase of light from minimum. A secondary minimum and maximum of velocity are correlated with the high maximum of light and the shallow minimum that follows it. During the increase of light, bright lines of hydrogen commonly appear on the violet edges of the hydrogen absorption lines, but in R Scuti the emission often becomes very strong and completely overshadows the absorption.

There was a time, soon after the RV Tauri class was first defined, when almost any semi-regular variable star had a good chance of being assigned to that class. More recently the group has been carefully limited to stars that have the well-defined characteristics described above, and the interlopers have been weeded out. As to the classification of the remaining semi-regular stars, various students of the subject are apparently not in agreement. Almost every conceivable gradation exists between Mira variables, RV Tauri stars, Cepheids, and utterly irregular red variables.

Among the most regular are SX Herculis (period 103 days, range 1.3 magnitudes, spectrum G7e) and X Monocerotis (155 days, 2.5 mag., Me). Both of these have been included formerly among the long-period variables, but SX Herculis could legitimately be called an extension of the Cepheid type. These two stars are typical of the groups we may call the yellow and the red semi-regular variables. Somewhat less regu-

lar is a group of stars of class M with longer periods: Z Ursae Majoris, W Cygni, and RS Cancri. All three of these show some resemblance to RV Tauri stars, but they cannot be considered true members of the class. Their light curves show marked changes of form, but their periods are well defined. Still less regular is AF Cygni, with an approximate 90-day period, but the deviations from regularity may add up to more than a full period.

DF Cygni is typical of a well-defined group of variables that show some resemblance to the RV Tauri type. They could indeed be called RV Tauri stars with a variation of large range and period of several hundred days superimposed on the variation of shorter period. Z Leonis represents a group of M stars of small range and short period, whose place in the scheme of things is uncertain. Their periods fall in the range between the Cepheids and the Mira stars, but they show no resemblance to the RV Tauri type, and they depart farther than any others from the period-spectrum relation.

Affinities with the Cepheids are shown by the yellow semi-regular variables SX Herculis, S Vulpeculae, AG Aurigae, and WW Tauri. AF Cygni represents a possible link with the irregular variables, such as X Herculis. No line of demarcation can be drawn anywhere except by arbitrary definition. It is not surprising that progress in the study of these stars has not been more rapid; the wonder is that so much order has been sorted out of the chaos.

For a number of years the writer observed R Scuti, W Cygni, and RS Cancri with a single-prism spectrograph and followed the light variations by making visual estimates. The spectral changes were well defined, as were the light curves, but the radial velocity curves were, at their best, only fairly well defined as to form and range, and at their worst they were utterly non-committal. In the cycles when the range of light was greatest, W Cygni showed clear variation of velocity with velocity minimum a little delayed after light maximum.[50] RS Cancri was disappointingly inconclusive. R Scuti was the most satisfactory of all, as the velocity variations were conspicuous and well defined. Variations of emission lines of all three stars were similar, though RS Cancri showed emission only seldom, and then rather weak. The hydrogen bright lines were strongest during the increase of light and faded soon after maximum, a considerable difference from their behavior in the long-period variables.

A good velocity curve by Joy[51] places SX Herculis squarely between the Cepheids and Mira stars as regards the correlation of light and radial velocity; light maximum comes near the middle of the decline of velocity. In the RV Tauri stars, including R Scuti, the correlation differs a little from this, in the direction of Cepheid-like trend.

The partial success of the studies of W Cygni makes such stars appear intriguing for higher-dispersion study. The field has been reconnoitered with one prism; three should be worth using for at least a few cycles.

This remark applies as well to R Scuti, in which greater precision is desirable. Good light curves, determined simultaneously, and coordinated spectrophotometric work might tell a good deal about the mechanism of semi-regular variation, particularly if we had equivalent data for Cepheids to use for comparison.

Aside from the RV Tauri stars and a very few others, we do not even know the general course of spectral changes, let alone radial velocities, of semi-regular stars. It will not do, however, to make sporadic observations. What is needed is a steady run covering completely several cycles, with each kind of observations. In the long run, such a program will produce more results per man-hour than two or three times as many uncorrelated or isolated observations. Among the fairly bright stars that need attention are AF Cygni and Z Ursae Majoris.

A few lingering doubts may haunt the student of RV Tauri stars. Is there a possibility that they are *binaries in process of fission,* pulsating for all they are worth? The remarkable distortion of the velocity curves of SX and RX Cassiopeiae and W Serpentis, the appearance of emission lines in their spectra, and their intrinsic variability, arouse a suspicion that they may be just far enough removed from the RV Tauri class to be recognizable as eclipsing binaries! Having set up the straw man, we proceed to knock him down; there is no vestige of similarity between the velocity curves of RV Tauri stars and those of the peculiar eclipsing systems. The writer has tried to warp an SX Cassiopeiae-like curve to fit an RV Tauri star, and has met only intolerable contradictions. There is no support for the belief that RV Tauri stars are pulsating binaries.

The Irregular Red Variables

We pass these by rather quickly with the remark that they need coordinated observations even more than do the semi-regular stars. On the other hand, the chance of their paying dividends in the form of conclusive results is considerably less. Betelgeuse[52] shows a distinct correlation of light and radial velocity variations in its long period of 2000 days, but little is known of the variations of shorter "period." On occasions the light variations in the cycle of a few months have been nearly equal to those of the long period. The writer has made a long series of one-prism observations of μ Cephei and finds it very similar to Betelgeuse. In both stars light maximum in the long period comes near the middle of the decline of velocity. The velocity ranges are small, and the one-prism velocities of μ Cephei are just accurate enough to give significant results. This star would be well worth study with three-prism dispersion through a few cycles. A somewhat fainter star of similar type, but with a larger range of light, is TW Pegasi.

An intriguing observation in the spectrum of Betelgeuse is the doubling of certain lines,[53] which indicates possible ejection of a considerable amount of gas. We may well ask whether this is of the same nature as

the more conspicuous doubling and shell ejection that occurs semi-regularly in 17 Leporis.[54] Is the doubling in Betelgeuse related at all to the variations of light? If so, to what extent are the variations of radial velocity due to unresolved double lines? The answering of such questions would require the use of the highest dispersion available for stellar spectra.

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(To be continued)

An Adventure in Galactic Research

By BART J. BOK

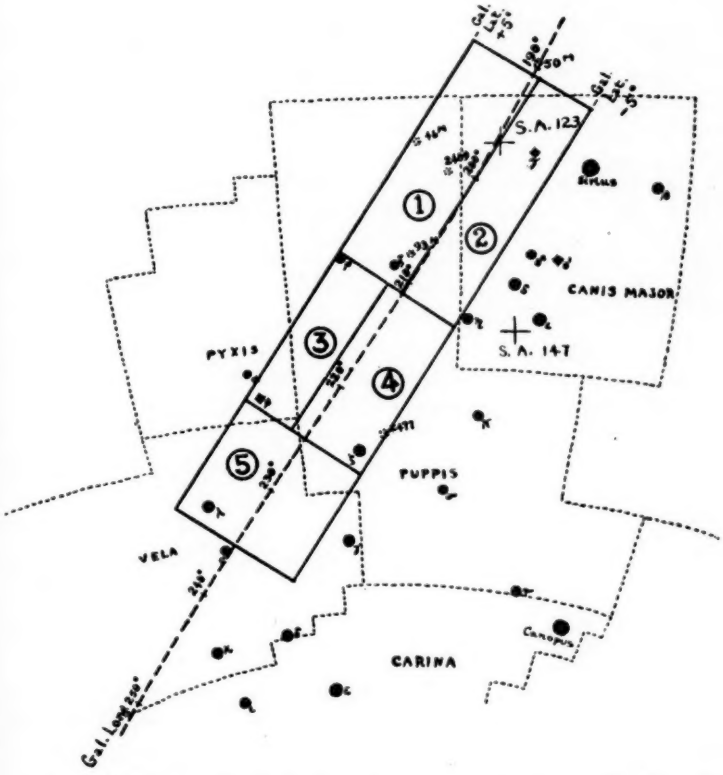
Shortly after the dedication of the Observatorio Astrofisico Nacional de Tonanzintla, Mexico, the director of the observatory, Luis Enrique Erro, extended to me an invitation to come for some months to Tonanzintla to work on the southern Milky Way. I went in November, 1944, and I was able to spend three months at Tonanzintla.

I had planned to carry on work on colors of early-type stars in Puppis and Vela, but when I arrived in Tonanzintla Sr. Erro suggested that we broaden this plan to include several other staff members. Those who took part in the work were Ing. Joaquin Ancona Albertos, the former rector of the University of Yucatan, now on the staff at Tonanzintla, Octavio Cano and Augustin Prieto, both graduate students, and the two Gonzalez sisters, Guillermina and Graciela. The planning and carrying out of the observing programs was largely the work of Sr. Erro, Guillermo Haro, and myself. Since the Schmidt camera was still going through certain final tests and adjustments, it was decided to depend mostly on the 3-inch Ross-Fecker camera, scale = 390″/mm.

The Milky Way in Puppis and Vela is of interest for a variety of reasons. The region under investigation, between declinations —12° and —47° is between galactic longitudes 195° and 235°. The northern part is a direct continuation of the Canis Major-Monoceros section, whereas to the south the brilliant star clouds of Carina are not far away. In its general appearance the Puppis-Vela section bears a close resemblance to the Canis Major-Monoceros section.

In the study of a particular section of the Milky Way, it is extremely important for the investigator to undertake in the early stages of the work a general study "by inspection" of the stellar distribution. For the Puppis-Vela region we made, therefore, first a preliminary survey with the naked eye and with binoculars, supplemented by a study of long-exposure photographs.

The best view of the Puppis-Vela section is had from Tonanzintla (Lat. 19° N) at Sidereal Times $7^h\,30^m$ to $8^h\,30^m$ when the region is near the meridian. The first general impression is that the region is strikingly uniform, with little to distinguish it from the smooth parts of the Milky Way in Gemini, Monoceros, and Canis Major, our familiar thin winter Milky Way. Upon closer examination a division of the region in five sub-regions is suggested (compare Figure).



The finder-chart has been reproduced by tracing from a portion of Map 8 in Norton's Star Atlas (A Star Atlas and Reference Handbook—epoch 1950—for Students and Amateurs; Arthur P. Norton; Gall and Inglis, 13 Henrietta Street, Strand W.C., London; 1943.). In the chart are indicated the five principal divisions referred to in the text. The galactic circle is shown as a heavy broken line; the galactic longitudes are marked along it. The positions of the clusters Messier 46, 50, and 93 and of N.G.C. 2409 and 2477 are indicated, as are the positions of two Kapteyn Selected Areas, 123 and 147.

1. Between galactic longitude $l = 190°$ and 211°, and galactic latitudes $b = 0°$ and $+5°$, the Milky Way is very smooth in appearance. There are some beautiful galactic clusters in this part of the sky, notably Messier 50 and 93 at the galactic circle and the handsome pair Messier 46, N.G.C. 2409, at $b = +3°$ to $+4°$. It is noted that the luminous band of the Milky Way thins out very gradually toward northern galactic latitudes. Long-exposure photographs with the 3-inch Ross camera and with the Tonanzintla Schmidt confirm the regularity of the stellar distribution for this section.

2. The corresponding section $l = 190°$ to $211°$, $b = 0°$ to $-5°$, exhibits some deficiency in star numbers and in surface brightness. Long-exposure photographs show that overlying this region there is a network of thin dark nebulae. The dark nebula near R.A. 7^h, Decl. $-11°$ (not far from Sirius) marks the beginning of a group of dark lanes, which can be traced all along the southern edge of the band of the Milky Way.

The nebula near Sirius is a very interesting one. Photographs by Bailey[1] and Ross[2] indicate that near the dark nebula there is quite a bit of bright nebulosity. A photograph by Haro with the Tonanzintla Schmidt shows that there are here some very dark lanes, which—not unlike the nebulae in Ophiuchus—have associated with them some very fine patches of bright nebulosity.

3. The section $l = 211°$ to $225°$, $b = +1°$ to $+5°$ shows a regular distribution very much like that of the first section. Only it is quite noticeable that the dark nebulae south of the Milky Way begin here to spread gradually into northern galactic latitudes.

4. The fourth section, $l = 211°$ to $225°$, $b = +1°$ to $-5°$, lies between η Canis Majoris and ζ Puppis. Irregularities in the stellar distribution are quite apparent to the naked eye. Long-exposure photographs with the 3-inch camera show that there are here, right at the galactic circle, some very pronounced dark nebulae. In this part are some early-type stars, which, according to Stebbins, Huffer, and Whitford, show quite marked reddening. Directly N.E. of ζ Puppis we find the beautiful cluster N.G.C. 2477.

5. The fifth section $l = 225°$ to $235°$, $b = -5°$ to $+5°$, lies between ζ Puppis and roughly the line marked by γ and λ Velorum. The distribution of surface brightness begins to be rather patchy. This region marks the northern boundary of the dark nebula in Vela.[3]

The comparison between the Milky Way in Puppis-Vela and in Carina can be made most effectively at Tonanzintla at Sidereal Times 11^h to 12^h. At those times the entire section $l = 180°$ to $270°$ is approximately parallel to the horizon with an altitude of $10°$ to $20°$. The general uniformity of surface distribution for $l = 180°$ to $250°$ can be seen very strikingly at that time. But is is quite noticeable that beyond $l = 250°$ the appearance changes abruptly, with the region between the η Carinae nebula and the southern Coal Sack *very much brighter* than the uniform section $l = 180°$ to $250°$.

The conclusion to be drawn from a first general inspection of the Milky Way in Puppis and Vela is evidently that we have here apparently a continuation of the smooth sections of Gemini, Monoceros, and Canis Major. At first sight the region appears to have little in common with the Carina, Crux, Centaurus section.

The Tonanzintla studies of the Puppis-Vela region were concerned

primarily with colors and starcounts. As a preliminary, Cano took several series of plates for the determination of the atmospheric extinction in blue, yellow, and red light. Ancona and Guillermina Gonzalez undertook to measure the color indices of O to B5 stars for four centers; Graciela Gonzalez and Prieto worked on the starcounts for the Puppis-Vela section. At the time of my departure in the middle of February, none of these programs had been completed, but all were well enough advanced for a first general description of results obtained. The observing program was about half done.

At the half way point of my visit, the supply of photographic plates gave out. A large order had gone in to Eastman Kodak long ago, but war orders made it impossible for them to deliver on time. On the day I left, the fresh supply of photographic plates was expected at any moment. *C'est la guerre . . .*

Cano's results for atmospheric extinction were interesting and in a way rather disappointing. Tonanzintla is at an altitude of 7500 feet and the atmosphere is very clear. On a good night one can see third-magnitude stars, literally "snap-out" when they set behind the volcanoes Popocatepetl or Ixtaccihuatl. Under these circumstances I had expected the extinction at the zenith to be of the order of 0.20 mag. for photographic light and half to two-thirds of that for red and yellow light. Cano's curves indicate, however, that even for the clear atmosphere of Tonanzintla the extinction at the zenith for photographic light is of the order of 0.30 mag. and that for photovisual light it is of the order of 0.20 mag.

The method of observation was simply one of photographing two Harvard Standard Regions at declination $+15°$ side by side on the same plate. The first plate is taken with one Standard Region near the zenith and just past the meridian and another Standard Region, with 6^h difference of right ascension and also at $\delta = +15°$, low in the east. Thirty to forty minutes later a second plate is taken of the same two regions and so on at regular intervals until on the last plate of the series the first Standard Region is photographed low in the west and the other almost near the zenith. From the measured differences between magnitudes in the two regions, differences of extinction can be derived and from these the total extinction at the zenith can then readily be found.

If more extensive observations confirm Cano's values for the coefficient of extinction at Tonanzintla, the limiting zenith distance for accurate photometric work would be about 60°. The celestial pole has at Tonanzintla a zenith distance of 71° and, at least for the photographic part of the spectrum, the use of polar comparisons for accurate photometry would seem inadvisable. It may, however, prove possible to make use of polar comparisons in the red and yellow on nights of exceptional quality.

The rather high value of the coefficient of extinction at Tonanzintla

may be due in part to the fact that all of Cano's plates were taken during the dry season; from December to May there is much dust in the air. It will be of interest to continue the observations throughout the year and to see if on clear nights during the rainy season the measured coefficient of extinction comes out as high as during the winter months.

At the time of my departure the investigation of the colors of O to B5 stars had been completed for only one region, with work on three additional centers well under way. Ancona's results for a center at $l = 200°$, near Messier 46 and N.G.C. 2422, indicate that directly at the galactic circle the absorption is quite high, even for the regions not obviously affected by local obscuration. This is confirmed by some colors measured by Stebbins, Huffer, and Whitford.[4] At $b = 0°$ the average absorption for photographic light amounts to 1.0 mag. per 1000 parsecs. The medium which produces the reddening thins out very rapidly as we move away from the galactic circle. At $b = +3°$ to $+5°$ the absorption is already much smaller, with an indicated average absorption of 0.3 mag. per 1000 parsecs. The latter result is in general agreement with the color excesses for Messier 46 (Cuffey[5]) and N.G.C. 2422 (Zug[6]), which indicate very little reddening for $b = +3°$ to $+5°$. The final reduction of Ancona's colors awaits a check on the zero point of the magnitudes in two Harvard Standard Regions.

The preliminary results of Guillermina Gonzalez indicate that for the clear regions near $l = 206°$ the absorption characteristics are very much the same as those found by Ancona at $l = 200°$.

In the extension of the color work for the O to B5 stars, special attention will be paid to two centers at $l = 216°$, one at $b = +3°$, the other at $b = -3°$. The first of these is in a rich region free from obscuration, whereas the second falls in a region of obvious obscuration. Very near the second center are three stars of which color excesses have been measured by Stebbins, Huffer, and Whitford.[4] All three stars show considerable reddening; the mean value of the absorption at 1000 parsecs is at least 2.5 mag. for the region affected by obscuration. A nearby cluster of Zug[6], N.G.C. 2439, indicates, however, a slightly smaller total absorption; about half the value of Stebbins, Huffer, and Whitford.

When I left Mexico the star counts were completed for photographic magnitudes 9.0 to 13.0; they had been made on 30 and 60 minute plates taken with the 3-inch Ross camera. The Mount Wilson magnitudes in Kapteyn Selected Area 123 and the magnitudes in Harvard Standard Region D4 were used as standards. The completion of the program will consist in the counting of a series of 120 minute plates to be taken with the 3-inch Ross camera and check plates for the magnitude sequences to be taken with the 3-inch Ross and the Tonanzintla Schmidt camera.

The available star counts confirm the presence of extended dark

nebulae, the most conspicuous of which are near

l	b
207°	−3°
215	−1
220	−3
225	−1

The 120-minute plates with the 3-inch camera, and the plates of long exposure to be taken with the Schmidt, should aid materially in the unravelling of the interconnected network of dark nebulae, but the available counts give already an indication that the absorptions in the denser portions of these nebulae may run as high as two or three magnitudes. The general star counts suggest distances of the order of 500 to 800 parsecs for most of the dark nebulae.

For Kapteyn Selected Area 123 at $\delta = -15°$, counts are available from the Mount Wilson Catalogue of Selected Areas. A preliminary analysis of these counts (using the absorption of 1 mag. per 1000 parsecs derived from the above-mentioned color data) indicates that the star densities are very nearly equal to unity up to a distance of 2500 parsecs from the sun. The preliminary counts for this Selected Area —which falls in a region free from local obscuration, but right in the galactic circle near $l = 196°$—show that there exists probably some excess of star density between 200 and 600 parsecs from the sun. Because of the uncertainty in the value of the coefficient of absorption, we cannot consider this excess as definitely established.

For the Puppis-Vela region the limit of completeness of the Henry Draper Catalogue is close to 9.0; the Henry Draper Extension spectra, which would go at least two magnitudes fainter, are unfortunately lacking for this section of the Milky Way. It is, however, of interest to see what results may be obtained from an analysis of the distribution of spectral types in the Henry Draper Catalogue. Two preliminary studies were made. In the first one the distribution of spectral types was investigated for some sections free from obvious local obscuration; in the second one a comparative study was made of the distribution in an obscured and adjacent relatively unobscured field.

The general distribution of spectral types to $m = 9.0$ is very similar for the Puppis Region and for the Monoceros Region.[7] For the very numerous B8 to A0 stars the star densities at distances between 100 and 500 parsecs of the sun are of the order of 0.11 star per 10,000 pc^3; the space densities seem to be somewhat greater at 500 parsecs than at 100 parsecs from the sun. For the A2 to A7 stars and for the F stars the numbers indicate the presence of a definite dropping off of the star densities within 300 parsecs of the sun. For the area in Puppis the number of O to B5 stars with $m = 8.0$ to 9.0 is only one-sixth of the number for an area of the same size in Carina-Centaurus and twice the number for an area of the same size in Monoceros; this is further proof for the similarity of distribution in the Puppis-Vela and Monoceros

regions and confirms the lack of resemblance of the distributions in Puppis-Vela and in Carina-Centaurus.

A comparison of the spectral distribution in the relatively unobscured section $l = 215°$ to $225°$, $b = 0°$ to $+5°$, shows the effect of the dark nebula only—and then very slightly—for the B8 to A0 stars with $m = 8.1$ to 9.0. This agrees with our earlier estimate of a distance of 500 to 800 parsecs for the dark nebulae in this part of the Milky Way; these dark nebulae are certainly not within 500 parsecs of the sun.

The above results are only preliminary and are subject to revision when the researches on the colors and star counts are completed. Much that is new may be learned when, after the war, the observatory at Tonanzintla will have the much desired objective prism for its Schmidt camera and when it will be possible to supplement the present researches with work on faint spectra and colors. The preliminary results suffice, however, already to make clear that the Puppis-Vela region is one of the more critical ones of the Milky Way. The comparative study of the Monoceros, Puppis-Vela, and Carina-Centaurus regions appears to be a most interesting topic for Milky Way research.

REFERENCES

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[4] Stebbins, Huffer, and Whitford, *Ap.J.*, **91**, 20, 1940.
[5] Cuffey, *Ap.J.*, **94**, 55, 1941.
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The Planets in September and October, 1945

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern War Time subtract 4 hours, Central War Time, 5 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. During these two months the sun will move, as usual, approximately four hours eastward, and about 22° southward. Its path will extend from Leo, through Virgo, to the western edge of Libra. It will pass just north of the bright star Spica about the middle of October. It will cross the equator on September 23, which crossing determines the time of the autumn equinox.

Moon. The phases of the moon will occur as follows:

	d	h
New Moon	Sept. 6	14
First Quarter	14	18
Full Moon	21	20
Last Quarter	28	11
New Moon	Oct. 6	6
First Quarter	14	10
Full Moon	21	6
Last Quarter	27	22

Mercury. Mercury will be at a point of greatest elongation west of the sun on September 6. At this time it will be a few degrees north of the sun which will be favorable for northern observers. This planet will rise more than an hour before the sun on and near this date. After this date it will move eastward more rapidly than the sun and pass the sun on the side opposite from the earth on October 2. It will then move east of the sun but will not again become visible during this period.

Venus. Venus will remain west of the sun during these two months. Its motion eastward will be more rapid than that of the sun, and consequently it will rise later from day to day. It will continue to be a morning star throughout this period, although at the end of October it will be only about an hour and a half west of the sun.

Mars. Mars will continue to fall behind the sun in their common eastward motion. This will cause Mars to rise earlier from day to day. On October 12 Mars will be in quadrature with the sun and near that date it will rise about midnight. Mars will be approaching the earth during this period. At the end of October it will be almost exactly one astronomical unit from the earth.

Jupiter. Jupiter will be overtaken by the sun on October 1. Until that time Jupiter will be east of the sun and after that time west of the sun. But throughout the two months it will be too near the sun to be visible. It will move eastward 47 minutes and southward about 4 degrees.

Saturn. Saturn will be visible in the morning sky during this period. It will rise earlier from day to day and on October 18, when it will be in quadrature with the sun, it will rise at midnight. Its course will lie between The Twins and Procyon from Gemini into Cancer.

Uranus. Uranus will be in quadrature, 90 degrees west of the sun, on September 10. At the beginning of this period it will be quite close to the planet Mars. Like Mars, therefore, it will be visible in the morning sky.

Neptune. Neptune will be in conjunction with the sun on September 29. This date being near the middle of the period, Neptune will first be east of the sun then west of the sun, but always too close for good observation. It will be moving slowly southeast in the western part of Virgo.

Occultation Predictions for September and October, 1945

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Date 1945		Star	Mag.	IMMERSION Greenwich C.T.	a	b	Angle E from N	EMERSION Greenwich C.T.	a	b	Angle E from N
				h m	m	m	°	h m	m	m	°
Occultations Visible in Longitude +72° 30′, Latitude +42° 30′											
Sept.	15	24 Sgtr	5.7	23 0.5	−2.2	+1.0	61	0 15.2	−2.1	−1.0	305
	15	25 Sgtr	6.4	23 21.8	−2.0	−0.1	103	0 48.1	−1.9	−0.3	261
	17	36 B.Capr	6.2	23 55.7	−1.8	+0.7	92	1 16.3	−1.9	+0.6	246
	19	128 B.Capr	6.5	1 42.4	−1.6	+1.1	51	2 58.2	−2.0	−0.2	267
	20	56 Aqar	6.4	3 44.9	−1.0	+1.2	31	4 49.6	−1.9	−0.7	272
	25	3 B.Taur	6.4	3 1.1	−0.6	+1.0	104	3 47.1	−0.1	+2.4	204
	26	180 B.Taur	6.2	2 19.8	+0.1	+1.3	83	3 11.6	0.0	+1.8	236
	26	85 H¹.Taur	6.0	8 46.9	−1.4	+1.8	45	9 57.8	−1.9	−0.8	276
	26	234 B.Taur	6.0	11 21.2	−1.4	+0.5	53	12 26.3	−0.9	−1.7	282
	27	*l* Taur	5.3	2 38.9	+0.1	+0.7	113	3 19.0	+0.5	+2.0	216
	28	14 B.Gemi	6.0	3 41.2	−0.7	−0.9	149	3 59.6	+1.4	+3.6	189
	28	η Gemi	3.7	5 42.4	−0.8	+0.5	120	6 29.1	0.0	+2.8	216
	29	58 Gemi	6.0	10 34.0	−1.9	+0.3	94	11 58.8	−2.0	−0.3	273
Oct.	2	107 B.Leon	6.3	10 10.8	−0.9	+1.6	84	11 20.5	−1.4	−0.5	310
	13	189 B.Sgtr	6.2	22 5.7	−2.0	−1.7	150	22 48.1	−1.8	+1.8	206
	16	27 Capr	6.2	3 35.0	−1.4	−1.6	101	4 30.0	0.0	+0.4	214
	17	29 Aqar m	6.5	2 1.6	−1.1	+0.9	36	3 8.6	−1.7	−0.9	271
	17	τ Sqar	4.2	20 51.4	−0.3	+0.9	112	21 39.2	−0.8	+2.3	212
	22	30 B.Taur	6.5	23 38.0	+0.3	+1.4	64	0 28.2	0.0	+1.4	253
	23	148 B.Taur	6.0	7 42.1	−0.7	+4.3	6	8 16.6	−2.2	−4.0	312
	23	162 B.Taur	6.3	11 17.9	..	..	151	11 34.9	..	..	183
	27	Mars	0.3	4 3.3	..	..	174	4 7.8	..	..	183
Occultations Visible in Longitude +91° 0′, Latitude +40° 0′											
Sept.	15	24 Sgtr	5.7	22 19.9	−1.6	+1.2	83	23 40.0	−1.8	0.0	295
	15	25 Sgtr	6.4	22 48.9	−1.3	+0.2	120	0 8.1	−2.3	+0.7	255
	17	53 Sgtr m	6.2	4 36.5	−0.4	+0.9	29	5 25.7	−1.8	−2.5	305
	17	274 B.Sgtr	6.1	4 43.2	−0.5	+0.6	34	5 36.9	−1.5	−2.2	299
	17	36 B.Capr	6.2	23 26.5	−1.1	+0.9	103	0 39.3	−1.8	+1.4	245
	19	128 B.Capr	6.5	1 9.2	−1.5	+1.8	47	2 19.5	−2.0	+0.4	280
	20	56 Aqar	6.4	3 23.0	−0.7	+2.8	6	4 6.3	−3.0	−1.0	300
	25	3 B.Taur	6.4	2 53.2	0.0	+1.1	93	3 41.3	+0.1	+2.0	220
	26	85 H¹.Taur	6.0	8 20.3	−0.7	+2.9	28	9 19.6	−2.4	−0.4	286
	26	234 B.Taur	6.0	10 49.6	−1.7	+1.2	55	12 5.0	−1.7	−0.8	270
	26	ε Taur	3.6	12 50.8	−1.4	−0.5	77	14 1.6	−0.9	−0.8	260
	27	ο Taur	4.8	12 17.5	−1.9	+1.0	58	13 29.6	−1.4	−1.7	288
	28	η Gemi	3.7	5 33.3	0.0	+0.9	103	6 24.1	+0.1	+1.9	235
	28	36 B.Gemi	6.0	11 20.1	..	..	9	11 42.4	..	..	339
	29	58 Gemi	6.0	10 0.9	−1.4	+1.0	92	11 20.7	−1.9	+0.9	265
Oct.	2	107 B.Leon	6.3	9 57.3	−0.2	+1.5	83	10 59.7	−0.9	+0.1	303
	14	208 B.Sgtr	6.2	1 59.6	−1.3	−0.2	61	3 13.1	−1.3	−1.4	278
	16	27 Capr	6.2	3 8.8	−1.7	−0.4	80	4 22.5	−0.8	−0.1	234
	17	29 Aqar m	6.5	1 38.7	−0.9	+2.4	11	2 27.9	−3.0	−1.2	298
	19	30 Psc	4.7	6 38.8	−2.4	−2.8	117	7 14.3	+0.2	+2.9	180
	24	330 B.Taur	6.3	11 47.9	−1.5	+0.4	55	12 49.1	−0.7	−1.9	291
	25	1 Gemi	4.3	10 34.3	..	..	22	11 10.0	..	..	330
	25	3 Gemi m	5.8	13 13.8	−1.3	−0.5	73	14 17.0	−0.4	−1.8	292
	27	Mars	0.3	.. ..	..	..	..	4 24.1	+0.9	+2.3	218
Occultations Visible in Longitude +120° 0′, Latitude +36° 0′											
Sept.	2	192 B.Gemi	6.3	12 38.3	−0.8	+1.1	91	13 50.2	−1.3	+1.2	265
	18	17 Capr	5.9	8 44.5	−2.4	−3.9	133	9 12.8	+1.1	+2.8	186
	20	56 Aqar	6.4	2 43.8	..	..	354	2 59.0	−1.2	−3.7	329
	26	234 B.Taur	6.0	10 1.9	−0.7	+2.8	30	11 4.2	−2.5	−0.2	282
	26	ε Taur	3.6	11 56.7	−2.1	+0.7	76	13 18.6	−1.9	+0.6	245
	27	ο Taur	4.8	11 20.2	−1.3	+2.2	49	12 34.7	−2.4	−0.2	279
	29	58 Gemi	6.0	9 34.1	−0.1	+1.6	71	10 36.7	−0.9	+0.9	278

Date 1943		Star	Mag.	IMMERSION Greenwich C.T.	*a*	*b*	Angle E from N	EMERSION Greenwich C.T.	*a*	*b*	Angle E from N
	°			h m	m	m	°	h m	m	m	°
Oct. 14	208	B.Sgtr	6.2	1 1.4	—2.5	+1.4	52	2 18.1	—2.6	—1.3	301
16	27	Capr	6.2	2 11.2	—2.0	+1.3	58	3 35.5	—2.3	+0.1	265
17	29	Aqar m	6.5	0 53.8	..	..	357	1 13.6	—1.4	—3.0	328
19	30	Psc	4.7	5 36.8	—1.9	+0.8	70	6 51.0	—1.3	+1.2	221
24	330	B.Taur	6.3	10 53.9	—1.9	+1.1	65	12 14.0	—2.0	—0.4	267
25	1	Gemi	4.3	9 43.8	..	..	9	10 12.6	..	..	326
25	3	Gemi m	5.8	12 26.6	+1.0	—0.4	101	13 46.8	—1.9	0.0	253
OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*											
Sept. 15	24	Sgtr	5.7	22 2.9	—0.9	+0.1	116	23 22.5	—2.2	+0.8	267
15	25	Sgtr	6.4	22 49.5	—0.1	—2.4	159	23 33.0	—3.4	+3.3	222
16	26	Sgtr	6.1	3 47.9	—0.7	+2.4	25	4 32.2	—2.8	—3.5	321
17	53	Sgtr m	6.2	4 22.3	—1.4	+0.8	47	5 32.8	—1.7	—1.4	284
17	274	B.Sgtr	6.1	4 31.2	—1.4	+0.6	51	5 43.3	—1.6	—1.3	280
17	36	B.Capr	6.2	23 18.3	—0.4	—0.7	137	0 6.4	—2.1	+2.8	217
19	128	B.Capr	6.5	0 41.5	—1.4	+1.5	69	1 59.1	—2.0	+0.9	263
20	56	Aqar	6.4	2 48.3	—1.4	+2.5	27	3 51.5	—2.7	—0.1	284
24	25	Arie	6.5	11 1.9	..	..	0	11 35.4	—2.3	—4.0	306
26	85	H³.Taur	6.0	7 49.8	—0.8	+2.2	45	9 1.3	—2.1	+0.8	264
26	234	B.Taur	6.0	10 27.2	—2.4	+0.4	82	11 50.4	—2.1	+1.1	237
26	ε	Taur	3.6	12 50.8	—2.0	—2.2	115	13 51.3	—1.6	+1.5	219
27	ο	Taur	4.8	11 58.9	—2.5	—0.2	92	13 24.3	—2.1	+0.3	249
28	η	Gemi	3.7	5 28.1	0.0	+0.1	120	6 7.0	+0.7	+2.1	217
28	36	B.Gemi	6.0	10 32.5	—1.5	+2.2	55	11 50.4	—2.6	—0.7	288
29	58	Gemi	6.0	9 45.8	—1.6	—0.2	118	10 51.7	—1.3	+2.6	233
Oct. 2	107	B.Leon	6.3	9 47.2	—0.1	+0.3	111	10 49.0	—0.5	+1.0	272
14	208	B.Sgtr	6.2	1 48.8	—2.1	—0.1	75	3 14.2	—1.5	—0.7	263
16	27	Capr	6.2	2 58.2	—2.6	—0.5	93	4 12.3	—0.9	+1.0	219
16	26	Capr	6.9	3 31.9	+0.6	+4.0	0	4 7.4	—4.0	—3.7	310
17	29	Aqar m	6.5	1 5.0	—1.7	+2.4	30	2 14.0	—2.9	—0.2	283
23	148	B.Taur	6.0	6 40.0	—0.4	+3.4	16	7 33.0	—3.0	—0.8	289
24	330	B.Taur	6.3	11 39.1	—1.8	—0.9	94	12 52.7	—1.3	—0.2	251
25	1	Gemi	4.3	9 56.2	—2.2	+1.3	66	11 19.9	—2.3	—0.9	281
25	3	Gemi m	5.8	13 15.3	—1.3	—1.8	113	14 23.1	—1.2	—0.3	253
25	6	Gemi	6.3	14 55.5	..	..	165	15 16.6	—2.4	+3.5	204
27	9	Canc	6.2	10 30.8	—2.1	+2.0	65	11 47.4	—2.3	—2.1	311

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U.S. Naval Observatory.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The year 1944 brought us as many meteor observations as might have been expected, when account is taken of the dislocation due to the war. We gained a large number of new members, the list of whom has already been published. Some of these are taking an active part in the work. Our principal handicap continues to be that so many of our best young male members are in the armed forces where conditions of life and work make meteor observations usually quite impossible. Nevertheless, we can point with much pride to several who have succeeded, on occasion, in getting in a few hours on meteors. These members have a

* before their names in the following table. It is quite possible that, in a few cases, it has been omitted unintentionally where I may not have been informed that the man was in service. Next, additional war activities have hampered others or even made observing impossible. As a minor cause, lack of gasoline has, occasionally, prevented groups from observing in the country under good conditions. Special commendation, this past year, should go to the group of young men connected with the Amateur Astronomers Association in New York City for the large amount of regular meteor observing they did.

The total for the year 13,669 observations of which we estimate fully 30% were plotted the rest described, or counted in hourly intervals, is quite heartening. By reference to the table published in the Notes of last August it will be seen that the total for 1944 is the largest since 1937, and not far from double those of the past three years. Perhaps one-tenth of the meteors in the table were observed in years previous to 1944 but not reported on time. Also as to last year, late as this is, still I have reason to know that several members have not yet sent in all the data in their possession. This delay is regrettable but I do not know how to prevent it. For ordinary meteors each is reported as an observation by every observer who saw it, unless in group counts. The casuals consist of single meteors not bright enough to be called fireballs, or counts of too few to be used as a basis for rates. As to fireballs, many more observations than the 157 in the table arrived here. For instance we had about 250 reports on that of August 18 alone. Following our custom as to fireballs, however, we attempt to give only the actual number of objects, whether one or several hundred reports come on each. In the column "Nights," *i.e.*, number of dates on which an observer worked, in general only those for which there was at least one hour of continuous observations are counted. In the last column, P denotes the meteors were (mostly) plotted, D described in tables, C counted per hour for rates, G means more than one person's results were combined in the number of meteors; any combination of these letters has an obvious meaning. Full details on rates for the months July and August were published in the Notes of November. When a group observed, to save space, we give only the name of the person who submitted the group's report.

As to telescopic meteors, the year's record is held by Cyrus Fernald of Wilton, Maine, who reported 80. These were seen during his extensive variable star observations for the A.A.V.S.O. Why we cannot induce most members of that society to send us such reports I do not know. Annual appeals are made to them, and I am sure I have the hearty support of Prof. Leon Campbell who is so intimately connected with their work. So once again their cooperation is urgently requested. Any member interested will, if he writes me, be sent the proper blanks and brief instructions, of course without charge. It is little trouble to anyone to make such reports and it would greatly aid meteoric astronomy for them to do so.

Perhaps the outstanding event of the year was the fireball (bolide) of August 18 which began over Ohio and ended over Illinois. (See December Notes.) The paths of other fireballs were also published. Several left long-enduring trains and considerable data on these important phenomena were collected. At present a new questionnaire for fireballs, to replace A.M.S. Bulletin No. 13, is being printed and should soon be ready for distribution. Plentiful supplies of maps and blanks are on hand. Many members still owe their $1 dues for 1945; please send it!

A cordial invitation is extended to all persons interested in astronomy, of either sex and any age from 18 upwards, to join as regular members, and interested young people from 13 to 18 to join as probational members. One can join by writing me his desire to do so, enclosing the $1 dues. The outfit of maps, blanks, instructions, etc., is then mailed. Many states have now no active members; we need many more in all of them.

Observer and Station	Nights	s →	
*Arslonian, Sgt. L., U.S.A. in England	1	29	C
Atwood, J. E., Encino, Calif.	7	44	P
Beetle, Miss D. E., Davis, Calif.	4	80	T
Beetle, Miss and others, Santa Cruz, Calif.	2	164	GC
Betty Jane, Miss, Nashville, Tenn.	1	32	C
Bidlake, Miss M., Longview, Wash.	4	209	C
Black, J. L., Cleveland, Ohio	1	7	P
Blaser, J., Fresno, Calif.	3	51	C
Blaser, Mrs. J., Fresno, Calif.	1	22	C
Borowitz, S., Bronx, N. Y.	20	241	P
Bones, B. R., Grants Pass, Ore.	1	43	C
Bostick, Dr. J. B., Fresno, Calif.	9	126	C
*Bronson, Sgt. M. R., Victorville, Calif.	1	110	GC
Buxborm, E., New York, N. Y.	8	51	P
Chlebrukow, R., Paterson, N. J.	3	110	P
Cieminski, L. J., Polonia, Wis.	1	33	GC
Cole, Mrs. R. M., Bryn Athyn, Pa.	1	18	D
Cole, M., Merced, Calif.	1	27	P
Courtney, T., Warm Springs, Ore.	2	41	C
Culbertson, A. M., Redwood City, Calif.	1	24	C
Darling, B. C., Lansing, Mich.	4	116	P
Deane, Miss M., Burlingame, Calif.	1	25	C
Dole, R. M., Cape Elizabeth, Maine	15	246	P
Dukon, W. J., Sioux Falls, S. D.	1	71	C
Ehman, C., Hartford, Conn.	48	518	CP
Ehman, Mrs. C., Hartford, Conn.	14	150	C
Epstein, E., Bronx, N. Y.	2	25	P
Farnsworth, Miss A., S. Hadley, Mass.	1	26	C
Finney, B., Bismarck, N. D.	1	58	GC
Fisher, D., Huntington, Pa.	9	73	C
Fitzsimmons, C. S., Sibley, Iowa	4	40	P
Frederick, Mrs. G. H., Echo, Ore.	2	49	C
Gehert, E. T., Oley, Pa.	3	112	C
George, Miss D., Albertville, Ala.	1	110	GC
*Gorson, R. O., Corpus Christi, Texas	1	170	D
Griffith, Miss J., Sarasota, Fla.	1	28	C
Hagen, S. S., Bismarck, N. D.	1	40	C
Halback, E. A. Milwaukee Astr. Soc. } Milwaukee, Wis.	3	447	PC
Herbert, H. L., Washington Crossing, Pa.	2	78	G
Holt, Dr. W. L., Kearsarge, N. H.	1	42	D
*Horton, Warrant Officer W. P., Utica, N. Y.	1	12	P
*Houston, Lt. W. S., W. Monroe, La.	1	34	GP
Hukill, R. M., Wilmington, Del.	3	147	C
Interplanetary Society, Bartlesville, Okla.	1	224	C
Jensen, Miss A. K., Silverton, Ore.	2	90	C
Johnson, L. C. F., Glendale, Calif.	2	25	C
Johnson, M. C., Des Moines, Iowa	4	20	P
Khan, Prof. M. A. R., Begumpet, India	67	1005	P
Klass, N. P., Dubuque, Iowa	10	225	P
Klass and others, Dubuque, Iowa	2	420	GC
Kemper, Father, Kerrsville, Texas	2	27	GC
Krespach, A. G., Hope, Ind.	1	80	GC
Latch, R. S., Riverton, N. J.	2	25	C

Observer and Station	Nights	S →	
Liller, Wm., Cambridge, Mass.	4	101	P
Liss, A., Philadelphia, Pa.	2	54	D
Long, Miss B., Dell Rapids, S. D.	4	164	C
Leerman, J. L., Baltimore, Md.	4	62	C
McElroy, A., Flower Observatory, Pa.	1	11	P
McKeon, Mrs. J. J., Titusville, N. J.	5	108	P
McKeon, Mrs. J. J. and others, Titusville, N. J.	1	48	GD
Madans, A., New York, N. Y.	7	240	PD
Marshall, Dr. R. K., Cook Observatory, Pa.	4	129	C
Merwyn, J., Eugene, Ore.	5	120	C
Merz, Miss L., Catonsville, Md.	1	16	C
Milwaukee Astr. Soc., U. of Milwaukee, Wis.	3	447	PC
Neale, J. J., New Haven, Conn.	2	40	GC
Olivier, C. P., Flower Observatory, Pa.	4	160	P
Olivier and others, Phoenixville, Pa.	1	90	GC
Orevic, E., Yonkers, N. Y.	15	402	D
Paliobagis, M., Columbus, Ohio	3	51	PD
Parker, W. W., Bethel, Vt.	6	135	D
Preucil, F., Joliet, Ill.	15	350	GC
Price, R., Fort Washington, Pa.	1	17	D
Pruett, J. H., Eugene, Ore.	2	54	C
Pruett, Mrs. J. H., Eugene, Ore.	2	50	C
Reilly, Miss E. F., North Hills, Pa.	2	113	GP
Rifkin, E. B., Baltimore, Md.	1	10	P
*Rosenblum, E., Camp Murphy, Fla.	1	90	C
Rule, J. O., Highland Park, Pa.	3	30	C
Sandmeyer, Miss E., Buhl, Idaho	14	490	C
Scheer, Mrs. D. W., Philadelphia, Pa.	1	34	D
Schilling, J. H., State College, Pa.	5	94	P
*Senter, Lt. V. E., San Francisco, Calif.	2	87	GC
Shanklin, D., Washington, D. C.	2	19	C
*Simpson, J. W., Airplane routes	9	255	D
Smith, Miss L., Milton, Pa.	2	43	PC
Speiler, H., Aurora, Ill.	6	13	P
Stapf, Miss H., N. Bronx, N. Y.	3	61	C
Stockman, C., Buffalo, N. Y.	3	13	P
Stowe, B., Bronx, N. Y.	15	346	P
Taylor, Miss R., Albertville, Ala.	1	118	GC
Taleporos, A., Sullivan Co., N. Y.	4	255	D
Thompson, Mrs. H. T., Eugene, Ore.	3	81	C
Thompson, Miss H., Eugene, Ore.	1	44	C
Tomlinson, E. H., Carney's Pt., N. J.	1	35	GC
Weitzenhoffer, K., Bronx, N. Y.	24	305	P
Wiedermann, Ch., Clifton, N. J.	1	107	P
Widing, K., Brainerd, Minn.	2	21	C
Whetsel, Mrs. F. M., Pendleton, Ore.	2	171	GC
*Wood, Lt. R. J., Shawnee, Okla.	4	1255	GC
Woodburn, J. J., Philadelphia, Pa.	7	34	P
Wrinn, J. J., Nangatuck, Conn.	3	50	GD
Young, C. N., Scio, Ore.	1	44	C
Total		13,293	
Casuals		122	
Fireballs		157	
Telescopic Meteors		97	
Grand Total		13,669	

Flower Observatory, Upper Darby, Pa., 1945 June 13.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

"The Old Moon in the Arms of the New"

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ABSTRACT

It is suggested that variations in the lunar earthshine may be due at times, in part at least, to intense meteoritic activity on the Moon. In view of this possibility, it may be worth-while to record the intensity of the earthshine, especially when rich showers of meteors are observed to be in progress here on the Earth.

On the first 2 or 3 evenings after the new Moon, and on the last 2 or 3 nights of visibility of the waning Moon, even a casual observer can see the faint glow of that portion of the Moon's disk outside the bright crescent, known as "the earthshine" or "the old Moon in the arms of the new." This phenomenon is due mainly to light from the sunlit Earth falling onto the dark portion of the Moon. The phases of the Moon as seen from the Earth are supplementary to those presented by the Earth to the Moon. Like the directly sunlit surface, the Moon's supplementary earthlit surface also varies in brightness, on account of changes in the Moon's distance, its position in the sky, the clearness of our atmosphere, *etc.*

Occasionally, apart from these variations, a decided increase is noticed in the extent or luminosity of the lunar surface visible under earthshine. This increase may be due to unusually fine weather on that hemisphere of the Earth facing the Moon. An extraordinary case of visibility of the full body of the Moon at its first quadrature, about 1921 November 7, described by Elihu Thompson, is on record.[1] Meteorological records may reveal the condition of our atmosphere on that date. An alternative explanation might be found in intense meteoritic activity on the Moon. From occultation phenomena, it is generally believed that there is hardly any atmosphere on the Moon. Bombardment of the nearly airless, practically unprotected, lunar surface by an unusually abundant swarm of meteorites, like, *e.g.*, that responsible for an early Leonid shower of meteors, may have given rise to the appearance. Even on the supposition, in conformity with the investigations of W. H. Pickering, A. C. D. Crommelin, and Lincoln La Paz,[2] that there still exists on the Moon an appreciable atmosphere—enough to produce incandescence of the meteorites passing thru it—the previously mentioned phenomenon may be attributed to meteoritic activity, in the form of meteors, in the lunar atmosphere itself.

It would be a profitable piece of research to correlate the luminosity of that portion of the Moon visible under earthshine with meteoric displays observed on our planet, and, if possible, with the general transparency of our own atmosphere. (During rich showers of meteors there would be hardly 3 hours' difference between the times of the meteoritic activities taking place on the Earth and those occurring on the Moon.) A paper by Walter H. Haas, "Concerning Pos-

sible Lunar Meteoric Phenomena,"[3] describes 2 lunar flares. Such incidents would be rather rare and very difficult to observe. It would be much easier to observe variations in the lunar earthshine. The aforementioned paper refers to Lincoln La Paz's observations of the earthshine, made with a 4-inch refractor in 1938. It would be interesting to know just what conclusions have been drawn from those observations.

REFERENCES

[1] *P. A.*, **30**, 109-10, 1922.
[2] *C.S.R.M.*, **2**, 35-40; *P. A.*, **46**, 277-82, 1938.
[3] *C.S.R.M.*, **3**, 98-101; *P. A.*, **51**, 397-400, 1943.

1945 March 9

Two Additional Criteria for Identifying Aerolites

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ABSTRACT

The "black" or non-metallic veins, and the magnetic properties, of aerolites can often be used as additional criteria for distinguishing these bodies from terrestrial stones.

It is obviously of the utmost importance in identifying meteorites to have available as many criteria as possible for distinguishing these bodies from similar samples of terrestrial material, for, as O. C. Farrington wisely remarked many years ago, "No single criterion can be given for distinguishing meteorites from masses of terrestrial origin. Only by combining several features can the positive determination of a meteorite be made."[1] That statement is just as true today as it was when it was written 30 years ago.

On pp. 87-8 of his "Meteorites," Farrington said: "[Chemical] analyses make it evident that the substance of the veins [of a meteorite; specifically, of an aerolite] does not differ essentially from that of the meteorite. The vein matter, therefore, has doubtless been formed by alteration in place of the substance of the meteorite and does not represent foreign matter introduced into a fissure, as is the case with most veins in terrestrial rocks. For this reason, therefore, the term *veins* [as] applied to these formations in meteorites is somewhat misleading, and the lack of analogy to veins in terrestrial rocks should be kept in mind."[2]

Here, then, is an additional criterion—and a comparatively simple one too—that is applicable in the practice of identifying aerolites—a characteristic feature of theirs that can be used to distinguish them from earthly stones: the so-called "black," *i.e.*, the non-metallic, veins of an aerolite have basically the same chemical composition as has the rest of the aerolite, while the veins of a terrestrial stone, being generally of the nature of an intrusive substance, differ normally in chemical composition from the remainder of the stone.[3]

Still another criterion that is of service in the work of identifying aerolites—that is, all except the very few that are totally devoid of free metal, formerly termed *asiderites*—is their magnetic properties; *i.e.*, their attraction by or their response to a magnet.[4] On account of the minute grains of nickel-iron that are scattered at random thruout their interiors and that constitute a considerable fraction of their mass, aerolites are commonly even more susceptible to a magnet than are most terrestrial stones of the same size that are magnetically affected.[5] It may be of interest in this connection to recall that the magnetic properties of

aerolites were taken advantage of in the recovery of the smallest meteorites on record—the tiny stones that were reclaimed in 1940 from ant hills at "Arntz," the site of the famous Holbrook, Arizona, aerolitic shower of 1912 July 19.[6]

That the magnetic properties of aerolites can be employed as a further means for recognizing them has been pointed out also by Mr. Oscar E. Monnig, in a paper entitled "A Supplementary Test for Meteorites."[7] This was read at the 8th Meeting of the Society for Research on Meteorites, held in Flagstaff, Arizona, on 1941 June 23-25, but has not, to my knowledge, since been published.

REFERENCES AND NOTES

[1] "Meteorites," p. 2, 1915.

[2] Reference should be made to the entire discussion of "Veins in Meteorites," ch. 9, pp. 85-91, *op. cit.*

[3] It should be noted that some aerolites have metallic, *i.e.*, nickel-iron, veins; *v.* Farrington, *op. cit.*, pp. 88-9.

[4] An "alnico" magnet has been found far superior to any other kind in recovering and testing meteorites, both aerolites and siderites.

[5] As is well known, the specific gravity of an aerolite is usually higher than that of an earthly stone; this fact is due probably, in large measure, to the included metal of the aerolite.

[6] H. H. Nininger, *C.S.R.M.*, **2**, 258-60; *P. A.*, **49**, 159-62, 1941. Frederick C. Leonard, *C.S.R.M.*, **2**, 288-91; *P. A.*, **49**, 384-7, 1941.

[7] Paper No. 12, *C.S.R.M.*, **2**, 296; *P. A.*, **49**, 443, 1941.

An Open Letter to the Editor

The Society for Research on Meteorites, since it was organized in 1933, has gone a long way in furthering our knowledge of meteorites. Ever since the war started and meteoritical research was curtailed, important discoveries have been —and still are being—made. As a member of the Society, I should like to offer two suggestions that may be of value to other members.

Would it not be a good idea to send each member a questionnaire and find out in what particular branch of the science of meteoritics he is specializing? A list could then be published so that each member would know the names of the other members who are interested particularly in the same lines he is. For instance, I am interested in field work on meteorites and also in meteorite craters, but I have not the necessary equipment and knowledge to do much work on chemical composition. If I knew what other members are interested in working on the same subjects I am, we might be able to help one another with our problems.

Another suggestion has to do with meteorite detectors. Since 1941, the Government has ordered a great many mine detectors that should be offered for sale thru the Surplus War Property Board, after the war has been won. I wrote the Board a few weeks ago to find out whether any detectors were yet available and whether they could be used to detect meteorites. According to the reply I received, none of these detectors has as yet been declared surplus property, and the Board does not believe that they would be of any value as meteorite detectors. I believe, however, that it would be a good idea to have a committee of the Society appointed to secure and to test some of these mine detectors. If they could be made to work, a good chance would be provided for members to obtain a needed detector at a reasonable price.

I trust that you will accept these suggestions in the spirit in which they are

given; *i.e.*, a sincere desire to be of help in furthering our knowledge of meteorites.

CLAUDE H. SMITH

R. D. No. 3, Waterloo, New York, May 12, 1945

[The Editor heartily endorses Mr. Smith's suggestions, which will be of interest, doubtless, to many other members of the Society.—F.C.L.]

"Geology Applied to Selenology" by J. E. Spurr (Review)

Having been asked to review this volume (viii + 112 pp., 4 pls., 23 figs., published and copyright by the author, 1944), I read it carefully and with interest. I made extensive notes with a view to criticizing it topic by topic. The principal thesis is not new, but a number of the detailed explanations were found to be novel and interesting. The author champions the hypothesis that the lunar features, for the most part, have been produced by the welling-up and collection of gases under the congealing crust of a liquid Moon and by the subsequent collapsing of these bubbles, the largest of which was equal in area to the States of New York, Pennsylvania, Ohio, Indiana, Illinois, and Missouri, combined. I recommend the book for interesting reading. Those who can go along with Mr. Spurr in his main thesis will find great stimulus in some of his ingenious explanations as to how various lunar features came into being. This communication is, however, no attempt at a systematic or comprehensive review of the book, for, after reading the "Addendum" (pp. 109-10), I find it more desirable to write a supplementary note explaining why the entire text becomes pointless, in so far as understanding the origin of the lunar features is concerned.

On p. 109, the author attempts to set aside the entire meteoritic explanation of the lunar features as being unworthy of his attention, saying that, altho he has studied carefully the literature on the subject, he has found nothing that would lead him to interpret any lunar feature as the result of meteoritic infall. Mr. Spurr states in the "Summary" at the beginning (p. viii) of his volume that the difference between the Earth and the Moon "is that the igneous phenomena of the Moon are the records of stiffening and hardening of the original crust, with attendant effervescence from the interior; while on the Earth the records of this pristine period have long since been obliterated." "This pristine period" on the Earth, according to geological thought (and I think Mr. Spurr would concur), ended more than a billion years ago, and even more remotely on the Moon. In the light of this assumption, let us look at some significant facts.

We know positively that, in the last one-thousandth part of that billion years (and in probably only a fraction of that fraction), the land portion of our planet has been struck at least 7 times by meteorites, or groups of meteorites, of sufficient size in each instance to produce, under conditions which Mr. Spurr and scientists generally assume to exist on the Moon, craters 5 to 20 miles in diameter. Besides these positively known examples of meteorite craters, there may logically be assumed to exist at least as many more in jungles and other little-known areas of the Earth's land surface, and 5 to 10 times as many more hidden under water bodies, all belonging to this recent period. In addition, there is that multitude of cosmically grouped and alined oval markings along the southeastern United States coast which (in the minds of those who have studied them most but have been slower than others in expressing their opinions!) have resulted probably from an impact far greater than that of all of the other known impacts combined. Then, too, astronomers have discovered, within a decade, that several planetoids

(or asteroids) actually encroach upon the domain delimited by the Earth's orbit and that one of these invaders, Hermes, scored a near miss (of only about 4 hours) on our planet on 1937 October 30. (*Cf.* a paper by the present writer in *C.S.R.M.*, **3**, 27-9; *P. A.*, **50**, 270-2, 1942.)

There is surely no factual reason for supposing that encounters with meteorites are more frequent now than they were in past geological time. On the other hand, there are reasons for suspecting that they have been even more frequent in the past. Certainly the Moon is subjected to a bombardment comparable to that which descends upon the Earth, with the very significant modification that our satellite has no protecting blanket of atmosphere to shield it from the cosmic blasting. The atmospheric bomb-shelter with which our own planet has surrounded itself is the equivalent in weight of a steel wall 54 inches thick! And, as a protection against missiles traveling at speeds of 7 to 45 miles per second, it is far more effective than steel would be! In spite of this elaborate protective shield, we know that within the past 140 years there have arrived upon the soil of the United States more than 25,000 meteorites ranging in size from that of a 22-caliber bullet to that of masses as large as 800 pounds, making an average of 180 arrivals each year. This result is based not on mere speculation; these are all *bona fide* specimens that have been collected from witnessed falls and that are, for the most part, still to be seen in the various museums thruout the world.

On the Moon, which is unprotected by an atmosphere, an orange-sized stony meteorite would, upon impact, explode with a violence equivalent to that of from 5 to 1500 pounds of nitroglycerin, depending upon the angle between its orbit and that of the Moon at their point of intersection and the consequent relative speed of the collision, while an 800-pound stone would be the equivalent of from 2 to 125 tons of nitroglycerin! It should be borne in mind that the aforementioned 180 arrivals per year on the Earth do not represent the total number of meteorites that penetrated the atmosphere above the United States. These 180 falls were the few from which representatives were found and preserved. A conservative estimate is that 90% of the arrivals were never found at all! Still more important is the fact that these survivors of the atmospheric encounter represent only a very small residue of the material that made the fatal plunge. Many a stone or iron that was completely disintegrated by the frictional "holocaust" would have produced a sizable craterlet, had it impinged upon the lunar surface. H. E. Wimperis (*Nature*, **71**, 82, 1904) estimated that no part of a meteorite of less than 10 to 20 pounds' weight ever survives to reach the soil (except as dust). After having carefully examined more than 10,000 specimens of freshly fallen meteorites as to their form, their fusion crust in relation to their interiors, the relative forms of members of the same shower, their distribution, and the size and nature of the dust clouds left in their wakes, I am convinced that Wimperis' estimate is not extravagant. When the foregoing facts are known, there is little cause for anyone to bother with the theoretical details that make up Mr. Spurr's book until that author has explained how any lunar features, developed in the course of that "pristine period," have managed to survive thruout a billion years.

Since it has been experimentally proved that missiles traveling at velocities above 4000 feet per second explode upon impact, and since it has been satisfactorily demonstrated that meteorites of several pounds' weight are being constantly consumed in our own atmosphere, it becomes important to give some consideration to the million or more meteorites per hour that are constantly plunging to their own destruction above us; for, while these bodies are too small to

produce any individual lunar features that could be seen from the Earth, many of them are of such size that they would produce moderately large craters under the lunar conditions of low gravitational force and lack of aerial resistance; and, since their rate of arrival is such that each square foot of surface has been blasted by 1500 of them in the course of the billion-year period, they must have accomplished considerable by way of erasing the results of the Moon's behavior during her "pristine" days.

There was a time when the question of what has happened on the Moon was anybody's guess. But in the course of the last few decades some very real facts have been gathered in regard to the intensity of the meteoritic bombardment experienced by the Earth. This bombardment is a cosmic process to which the Moon is of necessity subjected in about the same degree as is the Earth; therefore, any valid discussion of the lunar features must henceforth take this process into account.

H. H. NININGER

1110 West Main Street, Artesia, New Mexico (temporary address), June, 1945

"A Meteoric Theory of the Origin of the Earth and Planets" by O. J. Schmidt (Review)

In *Comptes Rendus (Doklady) de l'Académie des Sciences de l'U.R.S.S., Nouvelle Série*, **45**, 229-33, 1944, a new hypothesis of the origin of the planets is put forward by O. J. Schmidt of the Institute of Theoretical Geophysics of the Academy of Sciences of the U.S.S.R.[1] The novel feature of this hypothesis[2] consists in ascribing the origin of the planets to an encounter between the Sun and a cloud of dark obscuring material, such as is observed to lie in the central plane of our galactic system. This dark nebula is postulated to have been composed of dust as well as of larger meteoritic units, a portion of which were captured by the Sun when, in moving on its galactic orbit, it passed thru the cloud. If the nebula had been of uniform density, the orbits of the captured particles would have been oriented obviously in all directions. Schmidt supposes, however, that the Sun did not pass centrally thru the cloud, but, instead, near one edge of it (or thru a region of non-uniform distribution of material). This circumstance would have resulted in a greater number of captured particles moving in one direction than in the other. Those moving in the retrograde direction would have been gradually eliminated by collisions with directly moving particles, so that the final product would be characterized by having the great majority of the bodies moving in one general direction around the Sun.

Within the swarm, continual interactions and collisions were supposed to take place, so that gradually the small particles coalesced into larger and larger masses; thus the planets were formed. Schmidt explains the fact that the orbits of the major planets are not greatly inclined to one another by assuming that the dark cloud was confined largely to the galactic plane; *i.e.*, that it was in the form of a flat sheet. Under the circumstances previously described, this condition would have tended to produce "capture orbits" which lay in a more or less restricted plane.

It remains to be seen whether any serious objections, dynamical or otherwise, will be brought forward to these ideas. It may be that some critics will regard some of the circumstances postulated by the hypothesis of Schmidt as too improbable or too specialized. Moreover, there are questions that may be disposed

of by a more detailed development; *e.g.*, one might expect that the median plane of a planetary system formed by such a process would lie at least approximately parallel to the galactic plane; actually, the inclination of the plane of the ecliptic to the galactic plane is about 60°.

Schmidt promises further expansion of his hypothesis to account for the axial rotation of the Sun and of the planets, the formation of satellites, and other matters.

GEORGE H. HERBIG

Lick Observatory, University of California, Mount Hamilton, 1945 May 27

[1] A preliminary note on this hypothesis appeared in *The Observatory*, **65**, 277-8, 1944.

[2] It is interesting to recall that the idea of an encounter of the Sun with a galactic nebula has been advanced (see N. T. Bobrovnikoff, *Publ. Astron. Soc. Pacific*, **41**, 101-4, 1929) to explain the origin, not of the planets, but of the Sun's cometary family.

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus 10

Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By **LEON CAMPBELL, Recorder**

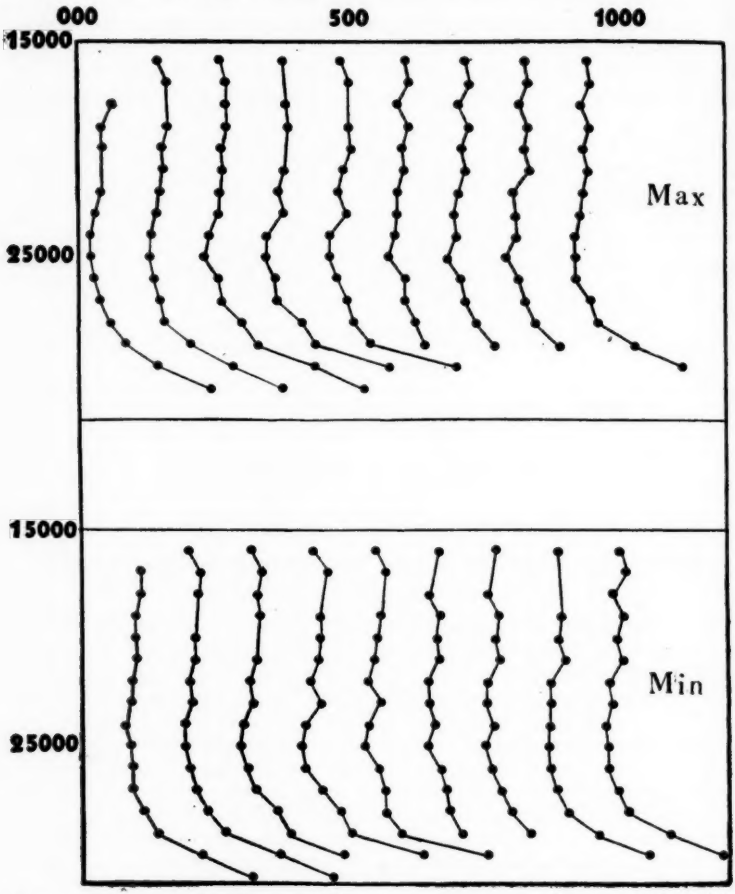
Changing Period of Z Aurigae: A. V. Nielsen of Copenhagen announces a somewhat radical lengthening of the period of the long-period variable Z Aurigae, 055353—spectrum M3—during recent years. He cites a present-day mean value of 135 days, as against a mean value of 111 days for all the epochs accessible in 1931.

The period of this star has been studied recently by the Recorder, who also finds that a decidedly longer period prevailed over the past six years than for the years 1902 to 1930.

Using the graphical method for studying changes of period as described in an earlier number of these Notes, and plotting separate curves for the dates of maxima and minima, we note a fairly constant mean period of 110.8 days for the years 1902 to 1930, a value of 113.5 days from 1930 to 1939, and 121.0 days from 1939 to 1945. Up to 1930 the changes in period can be well represented by a straight line drawn through the points, but from that time on there was a gradual increase in period, becoming still larger in more recent years. To be sure, Z Aurigae is a variable of only moderate range, about a magnitude, and at times varying somewhat irregularly, as is found to be the case for such other non-emission M-stars, nevertheless these separate discussions of entirely independent observations leaves little doubt in the reality of the change of period as has been indicated.

In the figures are shown the separate curves for maxima and minima, with every ninth epoch connected to illustrate the trend of the period. If the period was an exact multiple of 1000 days and there were no errors of observation or determination, the respective curves would follow a perpendicular line from top

to bottom, but it is readily seen that such is not the case for this variable.



PLOTS OF DATES OF MAXIMUM AND MINIMUM PHASES OF Z AURIGAE (1902-1945)

Miscellaneous Notes on the Variables: The asteroid Vesta was "rediscovered" independently in the field of U Virginis by two of our observers, Messrs. P. O. Parker of Griffin, Georgia, and Donald Mary of Baton Rouge, Louisiana.

According to reports from L. C. Peltier, T Coronae Borealis, the nova of 1866, recently decreased in light nearly a magnitude, compared to what it had been over the past twenty years during which he has been observing this star.

Gamma Cassiopeiae appears to have increased in brightness since the beginning of the present year. In November, 1944, it was of magnitude 2.9, and in April, 1945, it attained a magnitude of 2.7; not a large increase, but still significant and well established.

A.A.V.S.O. Council Meeting: The Council of the A.A.V.S.O. held a short business meeting at the Yale Observatory on June 17. Twenty-four candidates were elected to active membership, and Dr. Julian L. Coolidge of Cambridge, Mass., was elected a Patron; this in recognition of his recent gift of a fine 6-inch Clark refractor to the Association.

Russell B. Jamieson, Morristown, N. J.
Reverend C. J. Renner, Castalia, Ohio
A. W. Mount, Fort Worth, Texas
William Liller, Cambridge, Mass.
Joseph L. Gossner, Cambridge, Mass.
Bruce Stowe, Bronxville, N. Y.
E. H. Pilsworth, Battle Creek, Mich.
Thomas A. Cragg, Los Angeles, Calif.
A. M. Blakely, West Haven, Conn.
Domingo Taboada, Puebla, Mexico
James C. Meaders, San Francisco, Calif.
Dr. James C. Bartlett, Baltimore, Md.
Richard H. Gemberling, Spokane, Wash.
James S. Pickering, East Orange, N. J.
John A. Fulton, Minneapolis, Minn.
Walter Houston
C. C. Pinckney, Birmingham, Ala.
Silas W. Becroft, Jr., Yalesville, Conn.
James E. Brugh, Swissvale, Pa.
Raymond L. Williams, Greene, N. Y.
L. C. Broecker, Bridgeport, Conn.
L. F. McCroskey, Portland, Oregon
Stanley F. Thorpe, Louisville, Ky.
Fred E. Jones, Allston, Mass.

The rather sudden increase in applications for membership is due in great part to the activities of Mr. Heines in securing solar observers.

First Report of the Solar Division of the A.A.V.S.O.: Mr. Neal J. Heines, Chairman of the Solar Division of the A.A.V.S.O., presented his first report at a recent meeting of the Council held in New Haven, Conn.

The formation of this division was authorized at the October, 1944, meeting of the Association, and, if we can judge by the report itself, this new division has been functioning with very evident success.

The purpose of this division is to co-ordinate the interest of sunspot observers, standardize and supply forms, establish a continuity of observations, collect the same, and distribute the results to those institutions in need of such data.

Members of the Committee are Rev. and Mrs. W. M. Kearons of West Bridgewater, Mass., Dr. H. Helm Clayton, Canton, Mass., Mr. H. B. Rumrill, Berwyn, Pa., Dr. D. H. Menzel, Cambridge, Mass., and Mr. Neal J. Heines, Paterson, N. J.

As of June 1, 1945, the division consisted of 53 members, 32 of whom are now sending in regular reports each month. The distribution of members covers Canada, and 18 states and the District of Columbia in this country.

One hundred and twenty-five reports were submitted to the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, an average of eighteen per month. Two thousand observations were listed in these reports. This Department has analyzed all the observations, and reduced the same to preliminary relative sunspot numbers. For the month of December, 1944, to May, 1945, inclusive, these numbers are 28.4; 20.3; 11.9; 18.5; 29.5; and 26.5, respectively, (the last month being estimated only).

The Solar Division acknowledges its indebtedness to Dr. John A. Fleming, Director of the Department of Terrestrial Magnetism of the Carnegie Institution, and to Alan H. Shapley, who has supervised the reductions and taken care of the necessary correspondence between that Department and the Solar Division. The Institution leaflet was supplied through the kindness of the Department. Dr. Clayton is planning the segregation of sunspot data to be used for research in meteorology. A second investigation is planned by Dr. J. C. Bartlett to study the granular surface of the sun.

Mr. Heines' report should encourage many members of the Association who

have the time and facilities at their disposal to take part in this program of research. He will supply instructions and necessary forms to those who desire to enroll as solar observers.

Observations for May and June: A total of 4634 observations—2272 in May and 2362 in June—were contributed by 42 observers, as listed herewith.

Observer	May—1945—June No. Var.	No. Ests.	No. Var.	No. Ests.	Observer	May—1945—June No. Var.	No. Ests.	No. Var.	No. Ests.
Blunck	13	14	22	25	Liller	7	7	..	..
Boone	18	19	5	5	Luft	14	79	13	52
Bouton	18	20	23	26	Mary	29	49	38	104
Buckstaff	12	20	18	37	Meek	..	..	28	148
Chandra	85	102	..	..	Mount	13	36	11	23
Cilley	14	28	19	46	Nadeau	53	62	61	63
Cousins	26	49	22	49	Oheim	48	124	53	104
Cragg	30	39	37	74	Oravec	9	26	9	29
Dafter	..	..	10	47	Parker	39	39	21	21
Duffie	38	60	..	..	Parks	28	43	23	35
Fernald	285	630	172	290	Peltier	60	88	56	95
Gemberling	..	..	4	12	Renner	21	28	16	27
Harris	22	22	9	9	Rosebrugh	16	115	10	54
Hartmann	..	..	85	91	Sill	..	..	43	45
Holt	99	159	53	55	Stowe	..	..	15	28
Houston	6	13	..	..	Taboada	16	18	..	..
Howarth	20	33	18	18	Topham	12	12	..	..
Hutchings	6	14	..	..	Webb	10	11	14	15
Itzigsohn	..	..	55	180	Weber	26	26	9	9
Kearons	42	56	26	38	Weitzenhoffer	..	..	2	2
Kelly	8	9	10	11					
de Kock	72	322	77	395	Totals		2272		2362

July 10, 1945.

Comet Notes

By G. VAN BIESBROECK

During the month of June announcement of two comet discoveries came from the Boyden station of the Harvard Observatory in South Africa. Both were made by the veteran comet observer D. du Toit.

The discovery of the first of these comets goes back however to April 9 at which time the following information was sent by radio to the Harvard College Observatory at Cambridge, Mass.:

DU TOIT COMET—MAGNITUDE 10
1945 April 9 R.A. $10^h\,58^m.8$ Dec. $-1°\,3'$ at 17^h U.T.
Daily motion 1^m East and $35'$ South

The comet was not found on plates taken at Cambridge and Oakridge; hence Dr. H. Shapley, director of the Harvard College Observatory and the central bureau for astronomical telegrams, did not broadcast the information but asked the southern observers by letter for confirmation of the announcement. Not until June 9 did a reply come by radiogram. It was then learned that the comet had been continuously observed for two months both at the Boyden Station and at the Union Observatory, Johannesburg and that Dr. Jackson at Capetown had computed a parabolic orbit. The rough position of the comet on June first was 13^h and $-25°$ but it was very faint by that time. This information was forwarded

on June 12 to the various observatories but was of no use since no orbit was communicated. If the original announcement had been transmitted in the normal way the comet could have been followed easily also by northern observers. Let us hope that telegraphic interchange, especially between friendly allied nations, will soon function normally at least in parts of the world no longer in the war zone.

Announcement of the second comet, dated June 15, contained the following data:

COMET DU TOIT, MAGNITUDE 10
1945 June 11 at 3^h U.T.: R.A. 1^h 8^m Dec. —20°
Daily motion 1^m 45^s west, 1° 7′ south.

The position was unfavorable for northern observers and the object does not seem to have been observed except in the southern hemisphere. A couple of weeks later the central bureau transmitted the following parabolic elements computed by Dr. J. Bobone at Cordoba (Argentina):

Perihelion time	1945 May 17.134 U.T.
Longitude of node	254°18′
Node to perihelion	280 8
Inclination	156 30
Perihelion distance	0.9979 astr. units

This indicated that the comet was moving rapidly southward and came within a short distance of the earth in the latter part of June. By July 1 the comet was due to turn northward. In the evening of June 10 the computed position being 14^h 55^m and —37° 40′ I swept that region at low altitude in twilight but could not see the object. It is probably already too faint now to be picked up from this side of the equator.

Except for the magnitude at discovery no further data are available so far concerning the physical appearance of either comet but they did evidently not become bright.

The periodic comets whose rediscovery has been mentioned previously have been under observation in June and July. COMET KOPFF brightened up to 10th magnitude in the beginning of July when L. Peltier in Delphos (Ohio) picked it up independently. It appeared as a round coma some 2′ in diameter with a sharp central condensation. The ephemeris given on p. 292 of the June issue remains very accurate. It is continued here although the comet will get fainter and at lower altitude for northern observers.

EPHEMERIS OF PERIODIC COMET KOPFF

1945	h	m	°	′
Aug. 3	15	51.6	—14	19
8	16	3.0		23
13		15.0		29
18		27.6		37
23		40.7		44
28	16	54.2		52
Sept. 2	17	8.0	—14	58

PERIODIC COMET PONS-WINNECKE remained much fainter than COMET KOPFF, and hardly reached 12th magnitude. It showed only a faint condensation in a large diffuse coma. It will soon be lost in the evening sky. PERIODIC COMET OTERMA has been recorded again near the ephemeris position but it remained very faint without indication of fluctuation.

Attempts by the writer at locating COMET VÄISÄLÄ 1944 *b* in the latter part of the night have not been successful so far.

Williams Bay, Wisconsin, July 14, 1945.

General Notes

Mrs. Edward A. Fath, who for many years has been the efficient secretary in the editorial office of POPULAR ASTRONOMY, discontinued this work on June 30. Since that date Mrs. Hester Wellman Meech has been filling this position.

Dr. Charles H. Smiley, who has been in charge of the Department of Astronony and Director of the Ladd Observatory of Brown University for a number of years, was promoted to the rank of Professor of Astronomy in Brown University on July 1.

Dr. Walter S. Adams, director of the Mount Wilson Observatory of the Carnegie Institution of Washington, was awarded the honorary degree of Sc.D. by the University of Chicago at the Spring Convocation on June 15, 1945. The citation was as follows: "An astrophysicist who discovered a method of determining the distances of the stars from their spectra and who developed spectrographic instruments of high dispersion for the study of the atmospheres of the stars."

Dr. Richard Prager, for the past six years Research Associate at the Harvard Observatory, died on July 20, in his 62nd year, following a protracted illness. Prior to coming to this country he had been for many years a member of the Berlin-Babelsberg Observatory. From 1910 to 1912 he had also served on the staff of the Observatory of Santiago de Chile. He was a noted astronomical bibliographer of variable stars, as evidenced by his published work at Berlin-Babelsberg and Harvard Observatories.

Dr. Van Biesbroeck Honored

In the afternoon of June 27 members of the staff of the Yerkes Observatory, their families and friends, gathered in the library of the Observatory in honor of Professor Georges Van Biesbroeck who retired on July 1 from active duty in the University of Chicago and became Professor Emeritus. Mr. Struve spoke of the profound influence which Mr. Van Biesbroeck has exerted upon all members of the scientific staff during the thirty years of his service at the Yerkes Observatory. He announced that Mr. Van Biesbroeck would continue his research work with undiminished energy, in particular his photographic observations of comets, asteroids, and proper motion stars with the Yerkes 24-inch reflector, and his visual and photographic observations of double stars and known proper motion stars with the 82-inch reflector of the McDonald Observatory. Mr. Chandrasekhar spoke for the staff of the Observatory and the faculty of the University and outlined Mr. Van Biesbroeck's scientific work. Mr. Morgan read a number of letters from astronomers at other institutions, and on behalf of the staff of the Observatory presented to Mr. and Mrs. Van Biesbroeck a set of phonograph records. After the session a tea was given on the Observatory lawn by the ladies of the Observatory.